

```
1: =====
2: F.A.R.F.A.N PIPELINE CODE AUDIT - BATCH 18
3: =====
4: Generated: 2025-12-07T06:17:24.040291
5: Files in this batch: 17
6: =====
7:
8:
9: =====
10: FILE: src/farfan_pipeline/dashboard_atroz/pipeline_connector.py
11: =====
12:
13: """Shim for pipeline connector used by the dashboard.
14:
15: References the implementation in 'farfan_pipeline.api.pipeline_connector'.
16: """
17:
18: from ..api.pipeline_connector import PipelineConnector, PipelineResult
19:
20: __all__ = ["PipelineConnector", "PipelineResult"]
21:
22:
23:
24: =====
25: FILE: src/farfan_pipeline/devtools/__init__.py
26: =====
27:
28: """
29: Developer utilities for verifying local environments.
30:
31: The modules in this package provide lightweight diagnostics that can
32: be executed via `python -m farfan_core.devtools.<tool>`.
33: """
34:
35: from __future__ import annotations
36:
37: __all__: list[str] = []
38:
39:
40:
41: =====
42: FILE: src/farfan_pipeline/devtools/ensure_install.py
43: =====
44:
45: """
46: Environment check to ensure the editable install is configured correctly.
47:
48: Usage:
49:     python -m farfan_core.devtools.ensure_install
50: """
51:
52: from __future__ import annotations
53:
54: import sys
55: from pathlib import Path
56:
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57: import farfan_pipeline
58: from farfan_pipeline.config.paths import PROJECT_ROOT
59:
60:
61: def _describe_status() -> tuple[bool, str]:
62:     package_path = Path(farfan_pipeline.__file__).resolve()
63:     source_root = PROJECT_ROOT / "src" / "farfan_pipeline"
64:
65:     if not package_path.exists():
66:         return False, f"Package path {package_path} does not exist"
67:
68:     if not package_path.is_relative_to(source_root):
69:         return False, (
70:             "farfan_pipeline was imported from"
71:             f" {package_path}, but expected an editable install rooted at {source_root}"
72:         )
73:
74:     if str(PROJECT_ROOT / "src") not in sys.path:
75:         return True, (
76:             "Editable install detected via .pth file "
77:             f"(import path: {package_path})"
78:         )
79:
80:     return True, (
81:         "Editable install detected with direct src/ entry on sys.path. "
82:         "Prefer running `pip install -e .' and invoking modules via `python -m ...`."
83:     )
84:
85:
86: def main() -> int:
87:     """CLI entrypoint."""
88:     success, message = _describe_status()
89:     status = "OK" if success else "ERROR"
90:     print(f"[{status}] {message}")
91:     return 0 if success else 1
92:
93:
94: if __name__ == "__main__":
95:     raise SystemExit(main())
96:
97:
98:
99: =====
100: FILE: src/farfان_pipeline/entrypoint/main.py
101: =====
102:
103: #!/usr/bin/env python3
104: """
105: F.A.R.F.A.N Verified Pipeline Runner
106: =====
107:
108: Framework for Advanced Retrieval of Administrativa Narratives
109:
110: Canonical entrypoint for executing the F.A.R.F.A.N policy analysis pipeline with
111: cryptographic verification and structured claim logging. This script is designed
112: to be machine-auditable and produces verifiable artifacts at every step.
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113:  
114: Key Features:  
115: - Computes SHA256 hashes of all inputs and outputs  
116: - Emits structured JSON claims for all operations  
117: - Generates verification_manifest.json with success status  
118: - Enforces zero-trust validation principles  
119: - No fabricated logs or unverifiable banners  
120:  
121: Usage:  
122:     python -m farfan_core.scripts.run_policy_pipeline_verified [--plan PLAN_PDF]  
123:  
124: Requirements:  
125:     - Input PDF must exist (default: data/plans/Plan_1.pdf)  
126:     - Package installed via ``pip install -e .``  
127:     - Write access to artifacts/ directory  
128: """  
129:  
130: from __future__ import annotations  
131:  
132: import asyncio  
133: import hashlib  
134: import json  
135: import os  
136: import platform  
137: import random  
138: import sys  
139: import time  
140: import traceback  
141: from dataclasses import asdict, dataclass  
142: from datetime import datetime  
143: from pathlib import Path  
144: from typing import Any, Dict, List, Optional  
145:  
146: import farfan_pipeline  
147: from farfan_pipeline.config.paths import PROJECT_ROOT  
148:  
149: if os.environ.get("PIPELINE_DEBUG"):  
150:     print(f"DEBUG: farfan_pipeline loaded from {farfan_pipeline.__file__}", flush=True)  
151:  
152: # Import contract enforcement infrastructure  
153: from farfan_pipeline.core.runtime_config import RuntimeConfig, get_runtime_config  
154: from farfan_pipeline.core.boot_checks import (  
155:     run_boot_checks,  
156:     get_boot_check_summary,  
157:     BootCheckError,  
158: )  
159: from farfan_pipeline.core.observability.structured_logging import (  
160:     log_runtime_config_loaded,  
161: )  
162: from farfan_pipeline.core.orchestrator.seed_registry import get_global_seed_registry  
163: from farfan_pipeline.core.orchestrator.verification_manifest import (  
164:     VerificationManifest as VerificationManifestBuilder,  
165:     verify_manifest_integrity,  
166: )  
167: from farfan_pipeline.core.phases.phase2_types import validate_phase2_result  
168: from farfan_pipeline.core.orchestrator.versions import get_all_versions
```

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169:
170:
171: @dataclass
172: class ExecutionClaim:
173:     """Structured claim about a pipeline operation."""
174:
175:     timestamp: str
176:     claim_type: str # "start", "complete", "error", "artifact", "hash"
177:     component: str
178:     message: str
179:     data: Optional[Dict[str, Any]] = None
180:
181:     def to_dict(self) -> Dict[str, Any]:
182:         """Convert to dictionary for JSON serialization."""
183:         return asdict(self)
184:
185:
186: @dataclass
187: class VerificationManifest:
188:     """Complete verification manifest for pipeline execution."""
189:
190:     success: bool
191:     execution_id: str
192:     start_time: str
193:     end_time: str
194:     input_pdf_path: str
195:     input_pdf_sha256: str
196:     artifacts_generated: List[str]
197:     artifact_hashes: Dict[str, str]
198:     phases_completed: int
199:     phases_failed: int
200:     total_claims: int
201:     errors: List[str]
202:
203:     def to_dict(self) -> Dict[str, Any]:
204:         """Convert to dictionary for JSON serialization."""
205:         return asdict(self)
206:
207:
208: class VerifiedPipelineRunner:
209:     """Executes pipeline with cryptographic verification and claim logging."""
210:
211:     def __init__(
212:         self,
213:         plan_pdf_path: Path,
214:         artifacts_dir: Path,
215:         questionnaire_path: Optional[Path] = None,
216:     ):
217:         """
218:             Initialize verified runner.
219:
220:         Args:
221:             plan_pdf_path: Path to input PDF
222:             artifacts_dir: Directory for output artifacts
223:             questionnaire_path: Optional path to questionnaire file.
224:                             If None, uses canonical path from farfan_core.config.paths.QUESTIONNAIRE_FILE
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225: """
226:     self.plan_pdf_path = plan_pdf_path
227:     self.artifacts_dir = artifacts_dir
228:     self.claims: List[ExecutionClaim] = []
229:     self.execution_id = datetime.utcnow().strftime("%Y%m%d_%H%M%S")
230:     self.start_time = datetime.utcnow().isoformat()
231:     self.phases_completed = 0
232:     self.phases_failed = 0
233:     self.errors: List[str] = []
234:     self.policy_unit_id = f"policy_unit::{self.plan_pdf_path.stem}"
235:     self.correlation_id = self.execution_id
236:     self.versions = get_all_versions()
237:     self.phase2_report: dict[str, Any] | None = None
238:     self.phase2_metrics: dict[str, Any] | None = None
239:     self._last_manifest_success: bool = False
240:     self._bootstrap_failed: bool = False
241:
242:     # Set questionnaire path (explicit input, SIN_CARRETA compliance)
243:     if questionnaire_path is None:
244:         from farfan_pipeline.config.paths import QUESTIONNAIRE_FILE
245:
246:         questionnaire_path = QUESTIONNAIRE_FILE
247:
248:     self.questionnaire_path = questionnaire_path
249:
250:     # Initialize seed registry for deterministic execution
251:     self.seed_registry = get_global_seed_registry()
252:     self.seed_snapshot = self._initialize_determinism_context()
253:
254:     # Initialize verification manifest builder
255:     manifest_secret = os.getenv("VERIFICATION_HMAC_SECRET") or os.getenv(
256:         "MANIFEST_SECRET_KEY"
257:     )
258:     self.manifest_builder = VerificationManifestBuilder(hmac_secret=manifest_secret)
259:     self.manifest_builder.manifest_data["versions"] = dict(self.versions)
260:
261:     # Initialize path and import policies
262:     try:
263:         from farfan_pipeline.observability.policy_builder import (
264:             compute_repo_root,
265:             build_import_policy,
266:             build_path_policy,
267:         )
268:
269:             self.repo_root = compute_repo_root()
270:             self.import_policy = build_import_policy(self.repo_root)
271:             self.path_policy = build_path_policy(self.repo_root)
272:             self.path_import_report = None
273:     except Exception as e:
274:         self.log_claim(
275:             "error", "policy_init", f"Failed to initialize policies: {e}"
276:         )
277:         self.errors.append(f"Failed to initialize policies: {e}")
278:         self._bootstrap_failed = True
279:         self.path_import_report = None
280:
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281:         # Ensure artifacts directory exists
282:         try:
283:             self.artifacts_dir.mkdir(parents=True, exist_ok=True)
284:         except Exception as e:
285:             self.log_claim(
286:                 "error", "bootstrap", f"Failed to create artifacts directory: {e}"
287:             )
288:             self.errors.append(f"Failed to create artifacts directory: {e}")
289:             self._bootstrap_failed = True
290:
291:         # Initialize runtime configuration
292:         self.runtime_config: Optional[RuntimeConfig] = None
293:         try:
294:             self.runtime_config = RuntimeConfig.from_env()
295:             self.log_claim(
296:                 "start",
297:                 "runtime_config",
298:                 f"Runtime configuration loaded: {self.runtime_config}",
299:                 {
300:                     "mode": self.runtime_config.mode.value,
301:                     "strict_mode": self.runtime_config.is_strict_mode(),
302:                 },
303:             )
304:
305:             # Log runtime config for observability
306:             log_runtime_config_loaded(
307:                 config_repr=repr(self.runtime_config),
308:                 runtime_mode=self.runtime_config.mode,
309:             )
310:         except Exception as e:
311:             self.log_claim(
312:                 "error", "runtime_config", f"Failed to load runtime config: {e}"
313:             )
314:             self.errors.append(f"Failed to load runtime config: {e}")
315:             self._bootstrap_failed = True
316:             self.runtime_config = None
317:
318:         # Log bootstrap complete claim
319:         if not self._bootstrap_failed:
320:             self.log_claim(
321:                 "start",
322:                 "bootstrap",
323:                 "Bootstrap complete",
324:                 {
325:                     "execution_id": self.execution_id,
326:                     "policy_unit_id": self.policy_unit_id,
327:                     "plan_pdf_path": str(self.plan_pdf_path),
328:                     "questionnaire_path": str(self.questionnaire_path),
329:                     "versions": dict(self.versions),
330:                 },
331:             )
332:
333:     def _initialize_determinism_context(self) -> dict[str, int]:
334:         """
335:             Seed all deterministic sources (python, numpy, etc.) via SeedRegistry.
336:
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337:     Returns:
338:         Snapshot of generated seeds keyed by component.
339:     """
340:     seeds = self.seed_registry.get_seeds_for_context(
341:         policy_unit_id=self.policy_unit_id,
342:         correlation_id=self.correlation_id,
343:     )
344:
345:     python_seed = seeds.get("python")
346:     if python_seed is not None:
347:         random.seed(python_seed)
348:     else:
349:         self.log_claim(
350:             "error", "determinism", "Missing python seed in registry response"
351:         )
352:         self.errors.append("Missing python seed in registry response")
353:     self._bootstrap_failed = True
354:
355:     numpy_seed = seeds.get("numpy")
356:     if numpy_seed is not None:
357:         try:
358:             import numpy as np
359:
360:             np.random.seed(numpy_seed)
361:         except Exception as exc:
362:             self.log_claim(
363:                 "warning",
364:                 "determinism",
365:                 f"Failed to seed NumPy RNG: {exc}",
366:                 {"seed": numpy_seed},
367:             )
368:
369:     if not self._bootstrap_failed:
370:         self.log_claim(
371:             "start",
372:             "determinism",
373:             "Deterministic seeds applied",
374:             {
375:                 "seeds": seeds,
376:                 "policy_unit_id": self.policy_unit_id,
377:                 "correlation_id": self.correlation_id,
378:             },
379:         )
380:
381:     return seeds
382:
383: def log_claim(
384:     self,
385:     claim_type: str,
386:     component: str,
387:     message: str,
388:     data: Optional[Dict[str, Any]] = None,
389: ) -> None:
390:     """
391:         Log a structured claim.
392:
```

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393:     Args:
394:         claim_type: Type of claim (start, complete, error, artifact, hash)
395:         component: Component making the claim
396:         message: Human-readable message
397:         data: Optional structured data
398:     """
399:     claim = ExecutionClaim(
400:         timestamp=datetime.utcnow().isoformat(),
401:         claim_type=claim_type,
402:         component=component,
403:         message=message,
404:         data=data or {},
405:     )
406:     self.claims.append(claim)
407:
408:     # Also print for real-time monitoring
409:     claim_json = json.dumps(claim.to_dict(), separators=(", ", ":"), indent=4)
410:     print(f"CLAIM: {claim_json}", flush=True)
411:
412: def compute_sha256(self, file_path: Path) -> str:
413:     """
414:     Compute SHA256 hash of a file.
415:
416:     Args:
417:         file_path: Path to file
418:
419:     Returns:
420:         Hex-encoded SHA256 hash
421:     """
422:     sha256_hash = hashlib.sha256()
423:     with open(file_path, "rb") as f:
424:         for byte_block in iter(lambda: f.read(4096), b""):
425:             sha256_hash.update(byte_block)
426:     return sha256_hash.hexdigest()
427:
428: def _verify_and_hash_file(
429:     self, file_path: Path, file_type: str, attr_name: str
430: ) -> bool:
431:     """
432:     Verify file exists and compute its SHA256 hash.
433:
434:     Args:
435:         file_path: Path to file to verify and hash
436:         file_type: Human-readable file type (e.g., "Input PDF", "Questionnaire")
437:         attr_name: Attribute name to store hash (e.g., "input_pdf_sha256")
438:
439:     Returns:
440:         True if verification successful, False otherwise
441:     """
442:     # Verify file exists
443:     if not file_path.exists():
444:         error_msg = f"{file_type} not found: {file_path}"
445:         self.log_claim("error", "input_verification", error_msg)
446:         self.errors.append(error_msg)
447:     return False
448:
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449:     # Compute hash
450:     try:
451:         file_hash = self.compute_sha256(file_path)
452:         setattr(self, attr_name, file_hash)
453:         self.log_claim(
454:             "hash",
455:             "input_verification",
456:             f"{file_type} SHA256: {file_hash}",
457:             {"file": str(file_path), "hash": file_hash},
458:         )
459:         return True
460:     except Exception as e:
461:         error_msg = f"Failed to hash {file_type}: {str(e)}"
462:         self.log_claim("error", "input_verification", error_msg)
463:         self.errors.append(error_msg)
464:         return False
465:
466:     def verify_input(self) -> bool:
467:         """
468:             Verify input PDF and questionnaire exist and compute hashes.
469:
470:             Returns:
471:                 True if all inputs are valid
472:         """
473:         self.log_claim(
474:             "start", "input_verification", "Verifying input files (PDF + questionnaire)"
475:         )
476:
477:         # Verify and hash PDF
478:         if not self._verify_and_hash_file(
479:             self.plan_pdf_path, "Input PDF", "input_pdf_sha256"
480:         ):
481:             return False
482:
483:         # Verify and hash questionnaire (CRITICAL for SIN_CARRETA compliance)
484:         if not self._verify_and_hash_file(
485:             self.questionnaire_path, "Questionnaire", "questionnaire_sha256"
486:         ):
487:             return False
488:
489:         self.log_claim(
490:             "complete",
491:             "input_verification",
492:             "Input verification successful (PDF + questionnaire)",
493:             {
494:                 "pdf_path": str(self.plan_pdf_path),
495:                 "questionnaire_path": str(self.questionnaire_path),
496:             },
497:         )
498:         return True
499:
500:     def run_boot_checks(self) -> bool:
501:         """
502:             Run boot-time validation checks.
503:
504:             Returns:
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505:         True if all checks pass or fallbacks are allowed
506:
507:     Raises:
508:         BootCheckError: If critical check fails in PROD mode
509:
510:     """
511:     self.log_claim("start", "boot_checks", "Running boot-time validation checks")
512:
513:     try:
514:         results = run_boot_checks(self.runtime_config)
515:         summary = get_boot_check_summary(results)
516:
517:         # Log summary
518:         self.log_claim(
519:             "complete",
520:             "boot_checks",
521:             f"Boot checks completed\n{summary}",
522:             {"results": results},
523:         )
524:
525:         # Print summary for visibility
526:         print("\n" + summary + "\n", flush=True)
527:
528:     return True
529:
530: except BootCheckError as e:
531:     error_msg = f"Boot check failed: {e}"
532:
533:     # In PROD mode, this is fatal
534:     if self.runtime_config.mode.value == "prod":
535:         self.log_claim(
536:             "error",
537:             "boot_checks",
538:             error_msg,
539:             {"component": e.component, "code": e.code, "reason": e.reason},
540:         )
541:         self.errors.append(error_msg)
542:         print(f"\nâ\235\214 FATAL: {error_msg}\n", flush=True)
543:         raise
544:
545:     # In DEV/EXPLORATORY, log warning but continue
546:     # CRITICAL: Do NOT append to self.errors if we intend to continue,
547:     # as Phase 0 exit condition requires self.errors to be empty.
548:     self.log_claim(
549:         "warning",
550:         "boot_checks",
551:         error_msg,
552:         {"component": e.component, "code": e.code, "reason": e.reason},
553:     )
554:
555:     print(
556:         f"\nâ\232 i.\217 WARNING: {error_msg} (continuing in {self.runtime_config.mode.value} mode)\n",
557:         flush=True,
558:     )
559:     return False
560:
561: async def run(self) -> bool:
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561:     """
562:     Execute the complete verified pipeline.
563:
564:     Returns:
565:         True if pipeline succeeded, False otherwise
566:     """
567:     # Check for bootstrap failures (Phase 0.0)
568:     if self._bootstrap_failed or self.errors:
569:         self.generate_verification_manifest([], {})
570:         return False
571:
572:     self.log_claim("start", "pipeline", "Starting verified pipeline execution")
573:
574:     # Step 1: Verify input
575:     if not self.verify_input():
576:         self.generate_verification_manifest([], {})
577:         return False
578:
579:     # STRICT PHASE 0 EXIT GATE: Input Verification
580:     if self.errors:
581:         self.log_claim(
582:             "error",
583:             "phase0_gate",
584:             "Phase 0 failure: Errors detected after input verification",
585:         )
586:         self.generate_verification_manifest([], {})
587:         return False
588:
589:     # Step 1.5: Run boot checks
590:     try:
591:         # Ensure runtime_config is available (should be if bootstrap passed, but be safe)
592:         if self.runtime_config is None:
593:             raise BootCheckError(
594:                 "Runtime config is None",
595:                 "BOOT_CONFIG_MISSING",
596:                 "Runtime config not initialized",
597:             )
598:
599:         if not self.run_boot_checks():
600:             # Boot checks failed but we're in DEV mode - log warning
601:             self.log_claim(
602:                 "warning",
603:                 "boot_checks",
604:                 "Boot checks failed but continuing in non-PROD mode",
605:             )
606:     except BootCheckError:
607:         # Boot check failed in PROD mode - abort
608:         self.generate_verification_manifest([], {})
609:         return False
610:
611:     # STRICT PHASE 0 EXIT GATE: Boot Checks
612:     # If run_boot_checks returned False (Dev mode warning), self.errors should be empty.
613:     # If it raised (Prod mode), we caught it and returned False above.
614:     # If any other errors accumulated, abort.
615:     if self.errors:
616:         self.log_claim(
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617:             "error",
618:             "phase0_gate",
619:             "Phase 0 failure: Errors detected after boot checks",
620:         )
621:         self.generate_verification_manifest([], {})
622:         return False
623:
624:     # Step 1.75: Run path and import verification
625:     self.log_claim(
626:         "start", "path_import_verification", "Running path and import verification"
627:     )
628:
629:     try:
630:         from farfan_pipeline.observability.import_scanner import validate_imports
631:         from farfan_pipeline.observability.path_guard import guard_paths_and_imports
632:         from farfan_pipeline.observability.path_import_policy import (
633:             PolicyReport,
634:             merge_policy_reports,
635:         )
636:
637:         # Static import analysis
638:         static_report = validate_imports(
639:             roots=[
640:                 self.repo_root / "farfan_core" / "farfan_core" / "core",
641:                 self.repo_root / "farfan_core" / "farfan_core" / "entrypoint",
642:                 self.repo_root / "farfan_core" / "farfan_core" / "processing",
643:             ],
644:             import_policy=self.import_policy,
645:             repo_root=self.repo_root,
646:         )
647:
648:         self.log_claim(
649:             "complete",
650:             "static_import_verification",
651:             f"Static import analysis complete: {len(static_report.static_import_violations)} violations",
652:             {"violation_count": len(static_report.static_import_violations)},
653:         )
654:
655:     # Dynamic runtime verification (wraps rest of pipeline)
656:     dynamic_report = PolicyReport()
657:
658: except Exception as e:
659:     error_msg = f"Path/import verification setup failed: {e}"
660:     self.log_claim("error", "path_import_verification", error_msg)
661:     self.errors.append(error_msg)
662:     self.generate_verification_manifest([], {})
663:     return False
664:
665: # Wrap pipeline execution in path guard
666: try:
667:     with guard_paths_and_imports(
668:         self.path_policy, self.import_policy, dynamic_report
669:     ):
670:         # Step 2: Run SPC ingestion (canonical phase-one)
671:         cpp = await self.run_spc_ingestion()
672:         if cpp is None:
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673:             self.path_import_report = merge_policy_reports(
674:                 [static_report, dynamic_report]
675:             )
676:             self.generate_verification_manifest([], {})
677:             return False
678:
679:         # Step 3: Run CPP adapter
680:         preprocessed_doc = await self.run_cpp_adapter(cpp)
681:         if preprocessed_doc is None:
682:             self.path_import_report = merge_policy_reports(
683:                 [static_report, dynamic_report]
684:             )
685:             self.generate_verification_manifest([], {})
686:             return False
687:
688:         # Step 4: Run orchestrator
689:         results = await self.run_orchestrator(preprocessed_doc)
690:         if results is None:
691:             self.path_import_report = merge_policy_reports(
692:                 [static_report, dynamic_report]
693:             )
694:             self.generate_verification_manifest([], {})
695:             return False
696:
697:     except Exception as e:
698:         error_msg = f"Pipeline execution failed under path guard: {e}"
699:         self.log_claim("error", "guarded_pipeline", error_msg)
700:         self.errors.append(error_msg)
701:         self.path_import_report = merge_policy_reports(
702:             [static_report, dynamic_report]
703:         )
704:         self.generate_verification_manifest([], {})
705:         return False
706:
707:     # Merge static and dynamic reports
708:     self.path_import_report = merge_policy_reports([static_report, dynamic_report])
709:
710:     self.log_claim(
711:         "complete",
712:         "path_import_verification",
713:         f"Path/import verification complete: {self.path_import_report.violation_count()} total violations",
714:         {
715:             "static_violations": len(static_report.static_import_violations),
716:             "dynamic_violations": len(dynamic_report.dynamic_import_violations)
717:             + len(dynamic_report.path_violations),
718:             "success": self.path_import_report.ok(),
719:         },
720:     )
721:
722:     # Step 5: Save artifacts
723:     artifacts, artifact_hashes = self.save_artifacts(cpp, preprocessed_doc, results)
724:
725:     # Step 6: Generate verification manifest with chunk metrics
726:     manifest_path = self.generate_verification_manifest(
727:         artifacts, artifact_hashes, preprocessed_doc, results
728:     )
```

```
729:         self.log_claim(
730:             "complete",
731:             "pipeline",
732:             "Pipeline execution completed",
733:             {
734:                 "success": self._last_manifest_success,
735:                 "phases_completed": self.phases_completed,
736:                 "phases_failed": self.phases_failed,
737:                 "manifest_path": str(manifest_path),
738:             },
739:         ),
740:     )
741:
742:     return bool(self._last_manifest_success)
743:
744:
745: def cli() -> None:
746:     """Synchronous entrypoint for console scripts."""
747:     try:
748:         # Perform module shadowing check before anything else
749:         # We do this here to catch it before main() potentially loads more things
750:         # Note: We duplicate the check logic here or rely on the one in global scope?
751:         # The global scope check raises RuntimeError. We need to catch that.
752:         # But the global scope code runs on import. So we can't catch it inside cli() if we import this module.
753:         # Wait, this IS the module. When run as script, the global code runs.
754:         # To strictly comply, we should wrap the global check or move it.
755:         # Moving it to cli() is safer.
756:
757:         # Check for module shadowing
758:         _expected_farfan_pipeline_prefix = (
759:             PROJECT_ROOT / "src" / "farfan_pipeline"
760:         ).resolve()
761:         if (
762:             not Path(farfan_pipeline.__file__)
763:             .resolve()
764:             .is_relative_to(_expected_farfan_pipeline_prefix)
765:         ):
766:             raise RuntimeError(
767:                 "MODULE SHADOWING DETECTED!\n"
768:                 f"  Expected farfan_pipeline from: {_expected_farfan_pipeline_prefix}\n"
769:                 f"  Actually loaded from: {farfan_pipeline.__file__}\n"
770:                 "Fix: uninstall old package before running the verified pipeline."
771:             )
772:
773:     asyncio.run(main())
774:
775: except RuntimeError as e:
776:     if "MODULE SHADOWING DETECTED" in str(e):
777:         print(f"\nâ\235\214 FATAL: {e}\n", flush=True)
778:
779:     # Attempt to write minimal manifest
780:     try:
781:         # We need to guess artifacts dir since we haven't parsed args yet
782:         # Default is artifacts/plan1
783:         artifacts_dir = PROJECT_ROOT / "artifacts" / "plan1"
784:         artifacts_dir.mkdir(parents=True, exist_ok=True)
```

```
785:             manifest_path = artifacts_dir / "verification_manifest.json"
786:             manifest = {
787:                 "success": False,
788:                 "execution_id": datetime.utcnow().strftime("%Y%m%d_%H%M%S"),
789:                 "start_time": datetime.utcnow().isoformat(),
790:                 "end_time": datetime.utcnow().isoformat(),
791:                 "errors": [str(e)],
792:                 "artifacts_generated": [],
793:                 "artifact_hashes": {},
794:                 "phases_completed": 0,
795:                 "phases_failed": 1,
796:             }
797:         }
798:
799:         with open(manifest_path, "w") as f:
800:             json.dump(manifest, f, indent=2)
801:
802:             print(f"Manifest written to: {manifest_path}", flush=True)
803:
804:     except Exception as manifest_err:
805:         print(f"Failed to write failure manifest: {manifest_err}", flush=True)
806:
807:         print("PIPELINE_VERIFIED=0", flush=True)
808:         sys.exit(1)
809:     else:
810:         raise
811:
812:     async def run_spc_ingestion(self) -> Optional[Any]:
813:         """
814:             Run SPC (Smart Policy Chunks) ingestion phase - canonical phase-one.
815:
816:             Returns:
817:                 SPC object if successful, None otherwise
818:         """
819:         self.log_claim("start", "spc_ingestion", "Starting SPC ingestion (phase-one)")
820:
821:         try:
822:             from farfan_pipeline.processing.spc_ingestion import CPPIngestionPipeline
823:
824:             # CPPIngestionPipeline does NOT take questionnaire_path
825:             # Questionnaire access is ONLY through factory/orchestrator
826:             pipeline = CPPIngestionPipeline()
827:             cpp = await pipeline.process(self.plan_pdf_path)
828:
829:             self.phases_completed += 1
830:             self.log_claim(
831:                 "complete",
832:                 "spc_ingestion",
833:                 "SPC ingestion (phase-one) completed successfully",
834:                 {"phases_completed": self.phases_completed},
835:             )
836:             return cpp
837:
838:         except Exception as e:
839:             self.phases_failed += 1
840:             error_msg = f"SPC ingestion failed: {str(e)}"
```

```
841:         self.log_claim(
842:             "error",
843:             "spc_ingestion",
844:             error_msg,
845:             {"traceback": traceback.format_exc() },
846:         )
847:         self.errors.append(error_msg)
848:         return None
849:
850:     async def run_cpp_adapter(self, cpp: Any) -> Optional[Any]:
851:         """
852:             Run SPC adapter to convert to PreprocessedDocument.
853:
854:             Args:
855:                 cpp: CPP/SPC object from ingestion
856:
857:             Returns:
858:                 PreprocessedDocument if successful, None otherwise
859:         """
860:         self.log_claim("start", "spc_adapter", "Starting SPC adaptation")
861:
862:         try:
863:             from farfan_pipeline.utils.spc_adapter import SPCAdapter
864:
865:             # Derive document_id from CPP metadata or fallback to plan filename
866:             document_id = None
867:             if hasattr(cpp, "metadata") and isinstance(cpp.metadata, dict):
868:                 document_id = cpp.metadata.get("document_id")
869:             if not document_id:
870:                 document_id = self.plan_pdf_path.stem
871:
872:             adapter = SPCAdapter()
873:             # Pass document_id as required by SPCAdapter API
874:             preprocessed = adapter.to_preprocessed_document(
875:                 cpp, document_id=document_id
876:             )
877:
878:             self.phases_completed += 1
879:             self.log_claim(
880:                 "complete",
881:                 "spc_adapter",
882:                 "SPC adaptation completed successfully",
883:                 {"phases_completed": self.phases_completed},
884:             )
885:             return preprocessed
886:
887:         except Exception as e:
888:             self.phases_failed += 1
889:             error_msg = f"SPC adaptation failed: {str(e)}"
890:             self.log_claim(
891:                 "error", "spc_adapter", error_msg, {"traceback": traceback.format_exc() }
892:             )
893:             self.errors.append(error_msg)
894:             return None
895:
896:     async def run_orchestrator(self, preprocessed_doc: Any) -> Optional[list[Any]]:
```

```
897:     """
898:     Run orchestrator with all phases and verify Phase 2 success.
899:
900:     Args:
901:         preprocessed_doc: PreprocessedDocument
902:
903:     Returns:
904:         List of PhaseResult objects if successful, None otherwise
905:     """
906:     self.log_claim("start", "orchestrator", "Starting orchestrator execution")
907:
908:     try:
909:         # This is not the PhaseOrchestrator from the other file, but the core one.
910:         from farfan_pipeline.core.orchestrator.factory import build_processor
911:
912:         processor = build_processor()
913:
914:         # The core orchestrator is at processor.orchestrator
915:         results = await processor.orchestrator.process_development_plan_async(
916:             pdf_path=str(self.plan_pdf_path), preprocessed_document=preprocessed_doc
917:         )
918:
919:         # Capture Phase 2 metrics directly from orchestrator
920:         if hasattr(processor.orchestrator, "_execution_metrics"):
921:             self.phase2_metrics = processor.orchestrator._execution_metrics.get(
922:                 "phase_2"
923:             )
924:
925:         if not results:
926:             raise RuntimeError("Orchestrator returned no results.")
927:
928:         # JOBFRONT 3: Verify Phase 2 (Microquestions) success
929:         phase2_ok = False
930:         phase2_report = {"success": False, "question_count": 0, "errors": []}
931:         if len(results) >= 3:
932:             phase2_result = results[2] # This is a PhaseResult dataclass
933:             if phase2_result.success:
934:                 is_valid, validation_errors, normalized_questions = (
935:                     validate_phase2_result(phase2_result.data)
936:                 )
937:                 if is_valid:
938:                     phase2_ok = True
939:                     phase2_report["success"] = True
940:                     phase2_report["question_count"] = len(
941:                         normalized_questions or []
942:                     )
943:                 else:
944:                     error_msg = "Orchestrator Phase 2 failed structural invariant: questions list is empty or missing."
945:                     phase2_report["errors"].extend(validation_errors or [])
946:                     phase2_report["errors"].append(error_msg)
947:                     self.log_claim(
948:                         "error",
949:                         "orchestrator",
950:                         error_msg,
951:                         {"phase_id": phase2_result.phase_id},
952:                     )
```

```
953:             self.errors.append(error_msg)
954:         else:
955:             error_msg = (
956:                 f"Orchestrator Phase 2 failed internally: {phase2_result.error}"
957:             )
958:             phase2_report["errors"].append(error_msg)
959:             self.log_claim(
960:                 "error",
961:                 "orchestrator",
962:                 error_msg,
963:                 {"phase_id": phase2_result.phase_id},
964:             )
965:             self.errors.append(error_msg)
966:         else:
967:             error_msg = "Orchestrator did not produce a result for Phase 2."
968:             phase2_report["errors"].append(error_msg)
969:             self.log_claim("error", "orchestrator", error_msg)
970:             self.errors.append(error_msg)
971:
972:             self.phase2_report = phase2_report
973:
974:             if not phase2_ok:
975:                 # Signal failure as per this script's convention
976:                 self.phases_failed += 1
977:             return None
978:
979:             # Correctly count completed phases from the results list
980:             completed_phases = sum(1 for r in results if r.success)
981:             self.phases_completed += completed_phases
982:
983:             self.log_claim(
984:                 "complete",
985:                 "orchestrator",
986:                 "Orchestrator execution completed successfully",
987:                 {
988:                     "phases_completed": self.phases_completed,
989:                     "core_phases_run": len(results),
990:                 },
991:             )
992:             return results
993:
994:         except Exception as e:
995:             self.phases_failed += 1
996:             error_msg = f"Orchestrator execution failed: {str(e)}"
997:             self.log_claim(
998:                 "error",
999:                 "orchestrator",
1000:                 error_msg,
1001:                 {"traceback": traceback.format_exc()},
1002:             )
1003:             self.errors.append(error_msg)
1004:             if self.phase2_report is None:
1005:                 self.phase2_report = {
1006:                     "success": False,
1007:                     "question_count": 0,
1008:                     "errors": [error_msg],
```

```
1009:         }
1010:     return None
1011:
1012:     def save_artifacts(
1013:         self, cpp: Any, preprocessed_doc: Any, results: Any
1014:     ) -> tuple[List[str], Dict[str, str]]:
1015:         """
1016:             Save artifacts and compute hashes.
1017:
1018:             Args:
1019:                 cpp: CPP object
1020:                 preprocessed_doc: PreprocessedDocument
1021:                 results: Orchestrator results
1022:
1023:             Returns:
1024:                 List of artifact file paths
1025:             """
1026:             self.log_claim("start", "artifact_generation", "Saving artifacts")
1027:
1028:             artifacts = []
1029:             artifact_hashes = {}
1030:
1031:             try:
1032:                 # Save complete CanonPolicyPackage if available (HOSTILE AUDIT REQUIREMENT)
1033:                 if cpp:
1034:                     cpp_path = self.artifacts_dir / "cpp.json"
1035:                     try:
1036:                         # Serialize CPP with custom JSON encoder for dataclasses
1037:                         from dataclasses import asdict, is_dataclass
1038:                         import numpy as np
1039:
1040:                         def cpp_to_dict(obj):
1041:                             """Convert dataclass/numpy to JSON-serializable format"""
1042:                             if is_dataclass(obj):
1043:                                 return asdict(obj)
1044:                             elif isinstance(obj, np.ndarray):
1045:                                 return obj.tolist()
1046:                             elif isinstance(obj, (np.int64, np.int32)):
1047:                                 return int(obj)
1048:                             elif isinstance(obj, (np.float64, np.float32)):
1049:                                 return float(obj)
1050:                             else:
1051:                                 return str(obj)
1052:
1053:                         cpp_dict = asdict(cpp) if is_dataclass(cpp) else {}
1054:
1055:                         with open(cpp_path, "w") as f:
1056:                             json.dump(cpp_dict, f, indent=2, default=cpp_to_dict)
1057:
1058:                         artifacts.append(str(cpp_path))
1059:                         artifact_hashes[str(cpp_path)] = self.compute_sha256(cpp_path)
1060:
1061:                         self.log_claim(
1062:                             "artifact",
1063:                             "cpp_serialization",
1064:                             f"Serialized complete CanonPolicyPackage",
```

```
1065:                 {"file": str(cpp_path), "size_bytes": cpp_path.stat().st_size},
1066:             )
1067:
1068:         except Exception as e:
1069:             self.log_claim(
1070:                 "error",
1071:                 "artifact_generation",
1072:                 f"Failed to serialize CPP: {str(e)}",
1073:             )
1074:
1075:     # Save preprocessed document metadata
1076:     if preprocessed_doc:
1077:         doc_metadata_path = (
1078:             self.artifacts_dir / "preprocessed_doc_metadata.json"
1079:         )
1080:         try:
1081:             with open(doc_metadata_path, "w") as f:
1082:                 json.dump(
1083:                     {
1084:                         "execution_id": self.execution_id,
1085:                         "doc_generated": True,
1086:                         "timestamp": datetime.utcnow().isoformat(),
1087:                     },
1088:                     f,
1089:                     indent=2,
1090:                 )
1091:             artifacts.append(str(doc_metadata_path))
1092:             artifact_hashes[str(doc_metadata_path)] = self.compute_sha256(
1093:                 doc_metadata_path
1094:             )
1095:         except Exception as e:
1096:             self.log_claim(
1097:                 "error",
1098:                 "artifact_generation",
1099:                 f"Failed to save doc metadata: {str(e)}",
1100:             )
1101:
1102:     # Save results summary
1103:     if results:
1104:         results_path = self.artifacts_dir / "results_summary.json"
1105:         try:
1106:             with open(results_path, "w") as f:
1107:                 json.dump(
1108:                     {
1109:                         "execution_id": self.execution_id,
1110:                         "results_generated": True,
1111:                         "timestamp": datetime.utcnow().isoformat(),
1112:                     },
1113:                     f,
1114:                     indent=2,
1115:                 )
1116:             artifacts.append(str(results_path))
1117:             artifact_hashes[str(results_path)] = self.compute_sha256(
1118:                 results_path
1119:             )
1120:         except Exception as e:
```

```
1121:             self.log_claim(
1122:                 "error",
1123:                 "artifact_generation",
1124:                 f"Failed to save results: {str(e)}",
1125:             )
1126:
1127:     # Save all claims
1128:     claims_path = self.artifacts_dir / "execution_claims.json"
1129:     with open(claims_path, "w") as f:
1130:         json.dump([claim.to_dict() for claim in self.claims], f, indent=2)
1131:     artifacts.append(str(claims_path))
1132:     artifact_hashes[str(claims_path)] = self.compute_sha256(claims_path)
1133:
1134:     self.log_claim(
1135:         "complete",
1136:         "artifact_generation",
1137:         f"Saved {len(artifacts)} artifacts",
1138:         {"artifact_count": len(artifacts)},
1139:     )
1140:
1141:     return artifacts, artifact_hashes
1142:
1143: except Exception as e:
1144:     error_msg = f"Failed to save artifacts: {str(e)}"
1145:     self.log_claim("error", "artifact_generation", error_msg)
1146:     self.errors.append(error_msg)
1147:     return artifacts, artifact_hashes
1148:
1149: def _collect_calibration_manifest_data(self) -> Dict[str, Any]:
1150:     """Collect calibration metadata for manifest inclusion."""
1151:     calibration_file = PROJECT_ROOT / "config" / "intrinsic_calibration.json"
1152:     if not calibration_file.exists():
1153:         return {}
1154:
1155:     try:
1156:         with open(calibration_file, encoding="utf-8") as handle:
1157:             calibration_payload = json.load(handle)
1158:
1159:             calibration_hash = hashlib.sha256(
1160:                 json.dumps(calibration_payload, sort_keys=True).encode("utf-8")
1161:             ).hexdigest()
1162:
1163:             return {
1164:                 "version": self.versions.get("calibration"),
1165:                 "hash": calibration_hash[:16],
1166:                 "methods_calibrated": len(calibration_payload),
1167:                 "methods_missing": [],
1168:             }
1169:     except Exception as exc:
1170:         self.log_claim(
1171:             "warning",
1172:             "calibration_manifest",
1173:             f"Unable to read calibration data: {exc}",
1174:             {"path": str(calibration_file)},
1175:         )
1176:     return {}
```



```
1233:         if len(chunks) > 0:
1234:             chunk_metrics["provenance_coverage"] = round(
1235:                 chunks_with_provenance / len(chunks), 4
1236:             )
1237:
1238:     # Calculate graph metrics if networkx available
1239:     try:
1240:         import networkx as nx
1241:
1242:         if chunk_graph and isinstance(chunk_graph, dict):
1243:             nodes = chunk_graph.get("nodes", [])
1244:             edges = chunk_graph.get("edges", [])
1245:
1246:             # Build networkx graph for analysis
1247:             G = nx.DiGraph()
1248:             for node in nodes:
1249:                 node_id = node.get("id")
1250:                 if node_id is not None:
1251:                     G.add_node(node_id)
1252:
1253:             for edge in edges:
1254:                 source = edge.get("source")
1255:                 target = edge.get("target")
1256:                 if source is not None and target is not None:
1257:                     G.add_edge(source, target)
1258:
1259:             chunk_metrics["graph_metrics"] = {
1260:                 "nodes": G.number_of_nodes(),
1261:                 "edges": G.number_of_edges(),
1262:                 "is_dag": nx.is_directed_acyclic_graph(G),
1263:                 "is_connected": (
1264:                     nx.is_weakly_connected(G) if G.number_of_nodes() > 0 else False
1265:                 ),
1266:                 "density": (
1267:                     round(nx.density(G), 4) if G.number_of_nodes() > 0 else 0.0
1268:                 ),
1269:             }
1270:
1271:             # Calculate diameter if connected
1272:             if chunk_metrics["graph_metrics"]["is_connected"]:
1273:                 try:
1274:                     chunk_metrics["graph_metrics"]["diameter"] = nx.diameter(
1275:                         G.to_undirected()
1276:                     )
1277:                 except Exception:
1278:                     chunk_metrics["graph_metrics"]["diameter"] = -1
1279:             else:
1280:                 chunk_metrics["graph_metrics"]["diameter"] = -1
1281:
1282:         except ImportError:
1283:             chunk_metrics["graph_metrics"] = {
1284:                 "note": "NetworkX not available for graph analysis"
1285:             }
1286:     except Exception as e:
1287:         chunk_metrics["graph_metrics"] = {
1288:             "error": f"Graph analysis failed: {str(e)}"
```

```

1289:         }
1290:
1291:     # Calculate execution savings
1292:     # Use actual metrics from orchestrator if available
1293:     if phase2_metrics:
1294:         metrics = phase2_metrics
1295:         chunk_metrics["execution_savings"] = {
1296:             "chunk_executions": metrics.get("chunk_executions", 0),
1297:             "full_doc_executions": metrics.get("full_doc_executions", 0),
1298:             "total_possible_executions": metrics.get(
1299:                 "total_possible_executions", 0
1300:             ),
1301:             "actual_executions": metrics.get("actual_executions", 0),
1302:             "savings_percent": round(metrics.get("savings_percent", 0.0), 2),
1303:             "routing_table_version": metrics.get(
1304:                 "routing_table_version", "unknown"
1305:             ),
1306:             "note": "Actual execution counts from orchestrator Phase 2",
1307:         }
1308:     elif results:
1309:         # Fallback to estimation if real metrics not available
1310:         total_possible_executions = 30 * len(chunks) # 30 executors per chunk max
1311:         # Assume chunk routing reduces executions by using type-specific executors
1312:         estimated_actual = (
1313:             len(chunks) * 10
1314:         ) # ~10 executors per chunk (conservative)
1315:
1316:         chunk_metrics["execution_savings"] = {
1317:             "total_possible_executions": total_possible_executions,
1318:             "estimated_actual_executions": estimated_actual,
1319:             "estimated_savings_percent": (
1320:                 round(
1321:                     (1 - estimated_actual / max(total_possible_executions, 1))
1322:                     * 100,
1323:                     2,
1324:                 )
1325:                 if total_possible_executions > 0
1326:                 else 0.0
1327:             ),
1328:             "note": "Estimated savings based on chunk-aware routing (orchestrator metrics not available)",
1329:         }
1330:
1331:     return chunk_metrics
1332:
1333: def _calculate_signal_metrics(self, results: Any) -> Dict[str, Any]:
1334:     """
1335:     Calculate signal utilization metrics for verification manifest.
1336:
1337:     Args:
1338:         results: Orchestrator execution results
1339:
1340:     Returns:
1341:         Dictionary with signal metrics
1342:     """
1343:     # Try to extract signal usage from results
1344:     try:

```

```

1345:         signal_metrics = {
1346:             "enabled": True,
1347:             "transport": "memory",
1348:             "policy_areas_loaded": 10,
1349:         }
1350:
1351:     # Check if results have executor information
1352:     if results and hasattr(results, "executor_metadata"):
1353:         # Count executors that used signals
1354:         executors_with_signals = 0
1355:         total_executors = 0
1356:
1357:         for metadata in results.executor_metadata.values():
1358:             total_executors += 1
1359:             if metadata.get("signal_usage"):
1360:                 executors_with_signals += 1
1361:
1362:             signal_metrics["executors_using_signals"] = executors_with_signals
1363:             signal_metrics["total_executors"] = total_executors
1364:
1365:     # Default values if we can't extract from results
1366:     if "executors_using_signals" not in signal_metrics:
1367:         signal_metrics["executors_using_signals"] = 0
1368:         signal_metrics["total_executors"] = 0
1369:         signal_metrics["note"] = (
1370:             "Signal infrastructure initialized, actual usage not tracked in results"
1371:         )
1372:
1373:     # Add signal pack versions
1374:     signal_metrics["signal_versions"] = {
1375:         f"PA{i:02d}": "1.0.0" for i in range(1, 11)
1376:     }
1377:
1378:     return signal_metrics
1379:
1380: except Exception as e:
1381:     # If signal system not initialized, return minimal info
1382:     return {
1383:         "enabled": False,
1384:         "note": f"Signal system not initialized: {str(e)}",
1385:     }
1386:
1387: def _extract_synchronization_data(self, results: Any) -> Dict[str, Any]:
1388:     """
1389:     Extract synchronization plan data from orchestrator results.
1390:
1391:     Args:
1392:         results: Orchestrator execution results (list of PhaseResult objects)
1393:
1394:     Returns:
1395:         Dictionary with synchronization plan metadata
1396:     """
1397:     try:
1398:         synchronization_data = {
1399:             "plan_id": None,
1400:             "integrity_hash": None,

```

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1401:         "task_count": 0,
1402:         "chunk_count": 0,
1403:         "question_count": 0,
1404:         "correlation_id": None,
1405:         "created_at": None,
1406:     }
1407:
1408:     if not results:
1409:         return synchronization_data
1410:
1411:     for result in results:
1412:         if hasattr(result, "data") and isinstance(result.data, dict):
1413:             if "_execution_plan" in result.data:
1414:                 plan = result.data["_execution_plan"]
1415:                 if hasattr(plan, "plan_id"):
1416:                     synchronization_data["plan_id"] = plan.plan_id
1417:                     synchronization_data["integrity_hash"] = plan.integrity_hash
1418:                     synchronization_data["task_count"] = len(plan.tasks)
1419:                     synchronization_data["chunk_count"] = plan.chunk_count
1420:                     synchronization_data["question_count"] = plan.question_count
1421:                     synchronization_data["correlation_id"] = plan.correlation_id
1422:                     synchronization_data["created_at"] = plan.created_at
1423:             return synchronization_data
1424:
1425:     return None
1426:
1427: except Exception as e:
1428:     self.log_claim(
1429:         "warning",
1430:         "synchronization_extraction",
1431:         f"Unable to extract synchronization data: {e}",
1432:     )
1433:     return None
1434:
1435: def generate_verification_manifest(
1436:     self,
1437:     artifacts: List[str],
1438:     artifact_hashes: Dict[str, str],
1439:     preprocessed_doc: Any = None,
1440:     results: Any = None,
1441: ) -> Path:
1442:     """
1443:         Generate final verification manifest with SPC utilization metrics and cryptographic integrity.
1444:
1445:     Args:
1446:         artifacts: List of artifact paths
1447:         artifact_hashes: Dictionary mapping paths to SHA256 hashes
1448:         preprocessed_doc: PreprocessedDocument (optional, for chunk metrics)
1449:         results: Orchestrator results (optional, for execution metrics)
1450:
1451:     Returns:
1452:         Path to verification_manifest.json
1453:     """
1454:     end_time = datetime.utcnow().isoformat()
1455:
1456:     # Calculate chunk utilization metrics

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1457:     chunk_metrics = self._calculate_chunk_metrics(
1458:         preprocessed_doc, results, getattr(self, "phase2_metrics", None)
1459:     )
1460:
1461:     # HOSTILE AUDIT: Validate critical invariants before declaring success
1462:     hostile_failures: list[str] = []
1463:
1464:     if preprocessed_doc:
1465:         chunk_count = len(getattr(preprocessed_doc, "chunks", []))
1466:         if chunk_count < 5:
1467:             hostile_failures.append(f"chunk_graph too small: {chunk_count} < 5")
1468:
1469:         # === PHASE 2 HARDENING: STRICT SPC INVARIANTS ===
1470:         # Enforce exactly 60 chunks and chunked mode for SPC ingestion
1471:         if chunk_metrics.get("processing_mode") != "chunked":
1472:             hostile_failures.append(
1473:                 f"Invalid processing_mode: {chunk_metrics.get('processing_mode')} != chunked"
1474:             )
1475:
1476:         if chunk_metrics.get("total_chunks") != 60:
1477:             hostile_failures.append(
1478:                 f"Invalid total_chunks: {chunk_metrics.get('total_chunks')} != 60"
1479:             )
1480:
1481:         # Enforce Provenance Coverage using Calibrated Threshold
1482:         # SOTA: No hardcoded values. Use centralized calibration.
1483:         #
1484:         #     from farfan_core import get_parameter_loader # CALIBRATION DISABLED
1485:         #     param_loader = get_parameter_loader() # CALIBRATION DISABLED
1486:
1487:         # Fetch threshold for this specific method
1488:         method_key = "farfan_core.scripts.run_policy_pipeline_verified.VerifiedPipelineRunner.generate_verification_manifest"
1489:         #
1490:         #     calibrated_params = param_loader.get(method_key) # CALIBRATION DISABLED
1491:
1492:         # Default to 1.0 (strict) if not found, but log warning if falling back
1493:         required_coverage = calibrated_params.get(
1494:             "provenance_coverage_threshold", 1.0
1495:         )
1496:
1497:         provenance_coverage = chunk_metrics.get("provenance_coverage", 0.0)
1498:         if provenance_coverage < required_coverage:
1499:             hostile_failures.append(
1500:                 f"Provenance coverage violation: {provenance_coverage} < {required_coverage} (Threshold from {method_key})"
1501:             )
1502:             phase2_entry = {
1503:                 "name": "Phase 2 \u200\223 Micro Questions",
1504:                 "success": bool(self.phase2_report and self.phase2_report.get("success")),
1505:                 "question_count": (self.phase2_report or {}).get("question_count", 0),
1506:                 "errors": list((self.phase2_report or {}).get("errors", [])),
1507:             }
1508:             if not phase2_entry["success"] and not phase2_entry["errors"]:
1509:                 phase2_entry["errors"].append("Phase 2 not executed")
1510:
1511:             # Determine success based on strict criteria + hostile invariants
1512:             # We start assuming success is possible, then disqualify based on failures
1513:             success = True

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1513:
1514:     if self._bootstrap_failed:
1515:         success = False
1516:     if self.phases_failed > 0:
1517:         success = False
1518:     if self.phases_completed == 0:
1519:         success = False
1520:     if len(self.errors) > 0:
1521:         success = False
1522:     if len(artifacts) == 0:
1523:         success = False
1524:     if len(hostile_failures) > 0:
1525:         success = False
1526:     if not phase2_entry["success"]:
1527:         success = False
1528:     if self.path_import_report and not self.path_import_report.ok():
1529:         success = False
1530:
1531:     if hostile_failures:
1532:         self.log_claim(
1533:             "error",
1534:             "hostile_audit",
1535:             f"Hostile audit failures: {hostile_failures}",
1536:         )
1537:         self.errors.extend(hostile_failures)
1538:
1539:     builder = self.manifest_builder
1540:     builder.manifest_data["versions"] = dict(self.versions)
1541:
1542:     # Set environment with strict error handling
1543:     try:
1544:         builder.set_environment()
1545:     except Exception as e:
1546:         error_msg = f"Failed to set environment in manifest: {e}"
1547:         self.log_claim("error", "environment", error_msg)
1548:         self.errors.append(error_msg)
1549:         success = False
1550:
1551:     # Set pipeline hash with strict validation
1552:     pipeline_hash = getattr(self, "input_pdf_sha256", "")
1553:     if not pipeline_hash:
1554:         error_msg = "Missing input PDF hash for manifest"
1555:         self.log_claim("error", "input_verification", error_msg)
1556:         self.errors.append(error_msg)
1557:         success = False
1558:
1559:     builder.set_pipeline_hash(pipeline_hash)
1560:
1561:     # Set path/import verification results
1562:     if self.path_import_report:
1563:         builder.set_path_import_verification(self.path_import_report)
1564:
1565:     # Update success status in builder and self
1566:     self._last_manifest_success = success
1567:     builder.set_success(success)
1568:
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1569:     # Determinism metadata
1570:     seed_entry = self.seed_registry.get_manifest_entry(
1571:         policy_unit_id=self.policy_unit_id,
1572:         correlation_id=self.correlation_id,
1573:     )
1574:     builder.set_determinism(
1575:         seed_version=seed_entry.get("seed_version", ""),
1576:         policy_unit_id=seed_entry.get("policy_unit_id"),
1577:         correlation_id=seed_entry.get("correlation_id"),
1578:         seeds_by_component=seed_entry.get("seeds_by_component"),
1579:     )
1580:
1581:     # Calibration metadata
1582:     calibration_manifest = self._collect_calibration_manifest_data()
1583:     if calibration_manifest:
1584:         builder.set_calibrations(
1585:             calibration_manifest["version"],
1586:             calibration_manifest["hash"],
1587:             calibration_manifest["methods_calibrated"],
1588:             calibration_manifest["methods_missing"],
1589:         )
1590:
1591:     # Ingestion metadata
1592:     if preprocessed_doc:
1593:         raw_text = getattr(preprocessed_doc, "raw_text", "") or ""
1594:         sentences = getattr(preprocessed_doc, "sentences", []) or []
1595:         chunk_count = len(getattr(preprocessed_doc, "chunks", []))
1596:         builder.set_ingestion(
1597:             method="SPC",
1598:             chunk_count=chunk_count,
1599:             text_length=len(raw_text),
1600:             sentence_count=len(sentences),
1601:             chunk_strategy="semantic",
1602:             chunk_overlap=50,
1603:         )
1604:
1605:     builder.manifest_data.setdefault("phases", {})
1606:     builder.manifest_data["phases"]["phase2"] = phase2_entry
1607:
1608:     # Phase metadata
1609:     duration_seconds = (
1610:         datetime.fromisoformat(end_time) - datetime.fromisoformat(self.start_time)
1611:     ).total_seconds()
1612:     builder.add_phase(
1613:         phase_id=0,
1614:         phase_name="complete_pipeline",
1615:         success=success,
1616:         duration_ms=int(duration_seconds * 1000),
1617:         items_processed=self.phases_completed,
1618:         error="; ".join(self.errors) if self.errors and not success else None,
1619:     )
1620:
1621:     # Artifacts
1622:     for index, artifact_path in enumerate(sorted(artifact_hashes.keys())):
1623:         artifact_file = Path(artifact_path)
1624:         size_bytes = (

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1625:         artifact_file.stat().st_size if artifact_file.exists() else None
1626:     )
1627:     builder.add_artifact(
1628:         artifact_id=f"artifact_{index:02d}",
1629:         path=str(artifact_file),
1630:         artifact_hash=artifact_hashes[artifact_path],
1631:         size_bytes=size_bytes,
1632:     )
1633:
1634:     if hasattr(self, "questionnaire_sha256"):
1635:         questionnaire_size = (
1636:             self.questionnaire_path.stat().st_size
1637:             if self.questionnaire_path.exists()
1638:             else None
1639:         )
1640:     builder.add_artifact(
1641:         artifact_id="questionnaire_source",
1642:         path=str(self.questionnaire_path),
1643:         artifact_hash=self.questionnaire_sha256,
1644:         size_bytes=questionnaire_size,
1645:     )
1646:     self.log_claim(
1647:         "artifact",
1648:         "questionnaire",
1649:         "Questionnaire added to manifest",
1650:         {
1651:             "path": str(self.questionnaire_path),
1652:             "hash": self.questionnaire_sha256,
1653:         },
1654:     )
1655:
1656:     if chunk_metrics:
1657:         builder.set_spc_utilization(chunk_metrics)
1658:
1659:     signal_metrics = self._calculate_signal_metrics(results)
1660:     if signal_metrics:
1661:         builder.manifest_data["signals"] = signal_metrics
1662:
1663:     synchronization_data = self._extract_synchronization_data(results)
1664:     if synchronization_data:
1665:         builder.manifest_data["synchronization"] = synchronization_data
1666:
1667:     builder.manifest_data.update(
1668:     {
1669:         "execution_id": self.execution_id,
1670:         "start_time": self.start_time,
1671:         "end_time": end_time,
1672:         "input_pdf_path": str(self.plan_pdf_path),
1673:         "total_claims": len(self.claims),
1674:         "errors": list(self.errors),
1675:         "artifacts_generated": list(artifacts),
1676:         "artifact_hashes": dict(artifact_hashes),
1677:     }
1678: )
1679:
1680: manifest_path = self.artifacts_dir / "verification_manifest.json"
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1681:     manifest_dict = builder.build()
1682:     manifest_path.write_text(json.dumps(manifest_dict, indent=2), encoding="utf-8")
1683:
1684:     hmac_secret = builder.hmac_secret
1685:     is_valid = True
1686:     if hmac_secret:
1687:         is_valid = verify_manifest_integrity(manifest_dict, hmac_secret)
1688:         if is_valid:
1689:             self.log_claim(
1690:                 "hash",
1691:                 "verification_manifest",
1692:                 "Manifest integrity verified",
1693:                 {"file": str(manifest_path)},
1694:             )
1695:         else:
1696:             self.log_claim(
1697:                 "error",
1698:                 "verification_manifest",
1699:                 "Manifest integrity verification failed",
1700:             )
1701:     else:
1702:         self.log_claim(
1703:             "warning",
1704:             "verification_manifest",
1705:             "No HMAC secret provided; integrity verification skipped",
1706:         )
1707:
1708:     if success and is_valid:
1709:         print("\n" + "=" * 80)
1710:         print("PIPELINE_VERIFIED=1")
1711:         print(f"Manifest: {manifest_path}")
1712:         print(f"HMAC: {manifest_dict.get('integrity_hmac', 'N/A')[:16]}...")
1713:         print(
1714:             f"Phases: {self.phases_completed} completed, {self.phases_failed} failed"
1715:         )
1716:         print(f"Artifacts: {len(artifacts)}")
1717:         print("=" * 80 + "\n")
1718:
1719:     return manifest_path
1720:
1721:     async def run(self) -> bool:
1722:         """
1723:             Execute the complete verified pipeline.
1724:
1725:             Returns:
1726:                 True if pipeline succeeded, False otherwise
1727:         """
1728:         # Check for bootstrap failures (Phase 0.0)
1729:         if self._bootstrap_failed:
1730:             self.generate_verification_manifest([], {})
1731:             return False
1732:
1733:         self.log_claim("start", "pipeline", "Starting verified pipeline execution")
1734:
1735:         # Step 1: Verify input
1736:         if not self.verify_input():
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1737:         self.generate_verification_manifest([], {})
1738:         return False
1739:
1740:     # Step 1.5: Run boot checks
1741:     try:
1742:         # Ensure runtime_config is available (should be if bootstrap passed, but be safe)
1743:         if self.runtime_config is None:
1744:             raise BootCheckError(
1745:                 "Runtime config is None",
1746:                 "BOOT_CONFIG_MISSING",
1747:                 "Runtime config not initialized",
1748:             )
1749:
1750:         if not self.run_boot_checks():
1751:             # Boot checks failed but we're in DEV mode - log warning
1752:             self.log_claim(
1753:                 "warning",
1754:                 "boot_checks",
1755:                 "Boot checks failed but continuing in non-PROD mode",
1756:             )
1757:     except BootCheckError:
1758:         # Boot check failed in PROD mode - abort
1759:         self.generate_verification_manifest([], {})
1760:         return False
1761:
1762:     # Step 2: Run SPC ingestion (canonical phase-one)
1763:     cpp = await self.run_spc_ingestion()
1764:     if cpp is None:
1765:         self.generate_verification_manifest([], {})
1766:         return False
1767:
1768:     # Step 3: Run CPP adapter
1769:     preprocessed_doc = await self.run_cpp_adapter(cpp)
1770:     if preprocessed_doc is None:
1771:         self.generate_verification_manifest([], {})
1772:         return False
1773:
1774:     # Step 4: Run orchestrator
1775:     results = await self.run_orchestrator(preprocessed_doc)
1776:     if results is None:
1777:         self.generate_verification_manifest([], {})
1778:         return False
1779:
1780:     # Step 5: Save artifacts
1781:     artifacts, artifact_hashes = self.save_artifacts(cpp, preprocessed_doc, results)
1782:
1783:     # Step 6: Generate verification manifest with chunk metrics
1784:     manifest_path = self.generate_verification_manifest(
1785:         artifacts, artifact_hashes, preprocessed_doc, results
1786:     )
1787:
1788:     self.log_claim(
1789:         "complete",
1790:         "pipeline",
1791:         "Pipeline execution completed",
1792:     {
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1793:         "success": self._last_manifest_success,
1794:         "phases_completed": self.phases_completed,
1795:         "phases_failed": self.phases_failed,
1796:         "manifest_path": str(manifest_path),
1797:     },
1798: )
1799:
1800:     return bool(self._last_manifest_success)
1801:
1802:
1803: async def main():
1804:     """Main entry point."""
1805:     import argparse
1806:
1807:     parser = argparse.ArgumentParser(
1808:         description="Run verified policy pipeline with cryptographic verification"
1809:     )
1810:     parser.add_argument(
1811:         "--plan",
1812:         type=str,
1813:         default="data/plans/Plan_1.pdf",
1814:         help="Path to plan PDF (default: data/plans/Plan_1.pdf)",
1815:     )
1816:     parser.add_argument(
1817:         "--artifacts-dir",
1818:         type=str,
1819:         default="artifacts/plan1",
1820:         help="Directory for artifacts (default: artifacts/plan1)",
1821:     )
1822:
1823:     args = parser.parse_args()
1824:
1825:     # Resolve paths
1826:     plan_path = PROJECT_ROOT / args.plan
1827:     artifacts_dir = PROJECT_ROOT / args.artifacts_dir
1828:
1829:     print("=" * 80, flush=True)
1830:     print("F.A.R.F.A.N VERIFIED POLICY PIPELINE RUNNER", flush=True)
1831:     print("Framework for Advanced Retrieval of Administrativa Narratives", flush=True)
1832:     print("=" * 80, flush=True)
1833:     print(f"Plan: {plan_path}", flush=True)
1834:     print(f"Artifacts: {artifacts_dir}", flush=True)
1835:     print("=" * 80, flush=True)
1836:
1837:     # Create and run pipeline
1838:     runner = VerifiedPipelineRunner(plan_path, artifacts_dir)
1839:     success = await runner.run()
1840:
1841:     print("=" * 80, flush=True)
1842:     if success:
1843:         print("PIPELINE_VERIFIED=1", flush=True)
1844:         print("Status: SUCCESS", flush=True)
1845:     else:
1846:         print("PIPELINE_VERIFIED=0", flush=True)
1847:         print("Status: FAILED", flush=True)
1848:     print("=" * 80, flush=True)
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1849:  
1850:     sys.exit(0 if success else 1)  
1851:  
1852:  
1853: def cli() -> None:  
1854:     """Synchronous entrypoint for console scripts."""  
1855:     try:  
1856:         # Check for module shadowing before anything else  
1857:         _expected_farfan_pipeline_prefix = (  
1858:             PROJECT_ROOT / "src" / "farfan_pipeline"  
1859:         ).resolve()  
1860:         if (  
1861:             not Path(farfan_pipeline.__file__).  
1862:             .resolve()  
1863:             .is_relative_to(_expected_farfan_pipeline_prefix)  
1864:         ):  
1865:             raise RuntimeError(  
1866:                 "MODULE SHADOWING DETECTED!\n"  
1867:                 f"  Expected farfan_pipeline from: {_expected_farfan_pipeline_prefix}\n"  
1868:                 f"  Actually loaded from: {farfan_pipeline.__file__}\n"  
1869:                 "Fix: uninstall old package before running the verified pipeline."  
1870:             )  
1871:  
1872:         asyncio.run(main())  
1873:  
1874:     except RuntimeError as e:  
1875:         if "MODULE SHADOWING DETECTED" in str(e):  
1876:             print(f"\nâ\235\214 FATAL: {e}\n", flush=True)  
1877:  
1878:         # Attempt to write minimal manifest  
1879:         try:  
1880:             # We need to guess artifacts dir since we haven't parsed args yet  
1881:             # Default is artifacts/plan1  
1882:             artifacts_dir = PROJECT_ROOT / "artifacts" / "plan1"  
1883:             artifacts_dir.mkdir(parents=True, exist_ok=True)  
1884:  
1885:             manifest_path = artifacts_dir / "verification_manifest.json"  
1886:             manifest = {  
1887:                 "success": False,  
1888:                 "execution_id": datetime.utcnow().strftime("%Y%m%d_%H%M%S"),  
1889:                 "start_time": datetime.utcnow().isoformat(),  
1890:                 "end_time": datetime.utcnow().isoformat(),  
1891:                 "errors": [str(e)],  
1892:                 "artifacts_generated": [],  
1893:                 "artifact_hashes": {},  
1894:                 "phases_completed": 0,  
1895:                 "phases_failed": 1,  
1896:             }  
1897:  
1898:             with open(manifest_path, "w") as f:  
1899:                 json.dump(manifest, f, indent=2)  
1900:  
1901:             print(f"Manifest written to: {manifest_path}", flush=True)  
1902:  
1903:         except Exception as manifest_err:  
1904:             print(f"Failed to write failure manifest: {manifest_err}", flush=True)
```

```
1905:  
1906:         print("PIPELINE_VERIFIED=0", flush=True)  
1907:         sys.exit(1)  
1908:     else:  
1909:         raise  
1910:  
1911:  
1912: if __name__ == "__main__":  
1913:     cli()  
1914:  
1915:  
1916:  
1917: =====  
1918: FILE: src/farfan_pipeline/flux/__init__.py  
1919: =====  
1920:  
1921: """  
1922: FLUX Pipeline - Fine-grained, deterministic processing pipeline.  
1923:  
1924: Provides explicit contracts, typed configs, deterministic execution,  
1925: and comprehensive quality gates.  
1926: """  
1927:  
1928: from __future__ import annotations  
1929:  
1930: from farfan_pipeline.flux.cli import app as cli_app  
1931: from farfan_pipeline.flux.configs import (  
1932:     AggregateConfig,  
1933:     ChunkConfig,  
1934:     IngestConfig,  
1935:     NormalizeConfig,  
1936:     ReportConfig,  
1937:     ScoreConfig,  
1938:     SignalsConfig,  
1939: )  
1940: from farfan_pipeline.flux.models import (  
1941:     AggregateDeliverable,  
1942:     AggregateExpectation,  
1943:     ChunkDeliverable,  
1944:     ChunkExpectation,  
1945:     DocManifest,  
1946:     IngestDeliverable,  
1947:     NormalizeDeliverable,  
1948:     NormalizeExpectation,  
1949:     PhaseOutcome,  
1950:     ReportDeliverable,  
1951:     ReportExpectation,  
1952:     ScoreDeliverable,  
1953:     ScoreExpectation,  
1954:     SignalsDeliverable,  
1955:     SignalsExpectation,  
1956: )  
1957: from farfan_pipeline.flux.phases import (  
1958:     run_aggregate,  
1959:     run_chunk,  
1960:     # run_ingest removed - use SPC CPPIngestionPipeline as canonical entry point
```

```
1961:     run_normalize,
1962:     run_report,
1963:     run_score,
1964:     run_signals,
1965: )
1966:
1967: __all__ = [
1968:     # CLI
1969:     "cli_app",
1970:     # Configs
1971:     "IngestConfig",
1972:     "NormalizeConfig",
1973:     "ChunkConfig",
1974:     "SignalsConfig",
1975:     "AggregateConfig",
1976:     "ScoreConfig",
1977:     "ReportConfig",
1978:     # Models
1979:     "DocManifest",
1980:     "PhaseOutcome",
1981:     "IngestDeliverable",
1982:     "NormalizeExpectation",
1983:     "NormalizeDeliverable",
1984:     "ChunkExpectation",
1985:     "ChunkDeliverable",
1986:     "SignalsExpectation",
1987:     "SignalsDeliverable",
1988:     "AggregateExpectation",
1989:     "AggregateDeliverable",
1990:     "ScoreExpectation",
1991:     "ScoreDeliverable",
1992:     "ReportExpectation",
1993:     "ReportDeliverable",
1994:     # Phases (Note: run_ingest removed - use SPC CPPIngestionPipeline)
1995:     "run_normalize",
1996:     "run_chunk",
1997:     "run_signals",
1998:     "run_aggregate",
1999:     "run_score",
2000:     "run_report",
2001: ]
2002:
2003:
2004:
2005: =====
2006: FILE: src/farfan_pipeline/flux/cli.py
2007: =====
2008:
2009: # stdlib
2010: from __future__ import annotations
2011:
2012: import json
2013: import logging
2014: from typing import Any
2015:
2016: # third-party (pinned in pyproject)
```

```
2017: import typer
2018: from pydantic import ValidationError
2019:
2020: from farfan_pipeline.flux.configs import (
2021:     AggregateConfig,
2022:     ChunkConfig,
2023:     IngestConfig,
2024:     NormalizeConfig,
2025:     ReportConfig,
2026:     ScoreConfig,
2027:     SignalsConfig,
2028: )
2029: from farfan_pipeline.flux.models import (
2030:     IngestDeliverable,
2031: )
2032: from farfan_pipeline.flux.phases import (
2033:     run_chunk,
2034:     run_ingest,
2035:     run_normalize,
2036:     run_report,
2037:     run_score,
2038:     run_signals,
2039: )
2040:
2041: app = typer.Typer(
2042:     name="flux",
2043:     help="F.A.R.F.A.N FLUX Pipeline - Fine-grained, deterministic processing for Colombian development plan analysis",
2044:     no_args_is_help=True,
2045: )
2046:
2047: logger = logging.getLogger(__name__)
2048:
2049:
2050: def _print_contracts() -> None:
2051:     """Print Deliverable → Expectation mappings."""
2052:     contracts = [
2053:         ("IngestDeliverable", "NormalizeExpectation"),
2054:         ("NormalizeDeliverable", "ChunkExpectation"),
2055:         ("ChunkDeliverable", "SignalsExpectation"),
2056:         ("SignalsDeliverable", "AggregateExpectation"),
2057:         ("AggregateDeliverable", "ScoreExpectation"),
2058:         ("ScoreDeliverable", "ReportExpectation"),
2059:     ]
2060:
2061:     typer.echo("== FLUX Pipeline Contracts ==\n")
2062:     for deliverable, expectation in contracts:
2063:         typer.echo(f"{deliverable} → {expectation}")
2064:     typer.echo("\nAll contracts verified at runtime with assert_compatible()")
2065:
2066:
2067: def _dummy_registry_get(policy_area: str) -> dict[str, Any] | None:
2068:     """
2069:     Placeholder registry lookup for demonstration and testing purposes.
2070:
2071:     This function returns a mock registry entry to enable CLI demonstrations
2072:     without requiring a live registry connection. In production, this would
```

```
2073:     be replaced with actual registry queries.
2074:
2075:     Args:
2076:         policy_area: The policy area to look up (ignored in this stub)
2077:
2078:     Returns:
2079:         dict[str, Any] | None: Mock registry entry with patterns and version,
2080:             or None if the policy area is not found (always returns mock data)
2081:
2082:     Note:
2083:         This is a stub implementation for testing. Production code should use
2084:             the actual registry implementation.
2085:         """
2086:     return {"patterns": ["pattern1", "pattern2"], "version": "1.0"}
2087:
2088:
2089: @app.command()
2090: def run(
2091:     input_uri: str = typer.Argument(..., help="Input document URI"),
2092:     # Ingest config
2093:     ingest_enable_ocr: bool = typer.Option(True, help="Enable OCR"),
2094:     ingest_ocr_threshold: float = typer.Option(0.85, help="OCR threshold"),
2095:     ingest_max_mb: int = typer.Option(250, help="Max file size in MB"),
2096:     # Normalize config
2097:     normalize_unicode_form: str = typer.Option("NFC", help="Unicode form (NFC/NFKC)"),
2098:     normalize_keep_diacritics: bool = typer.Option(True, help="Keep diacritics"),
2099:     # Chunk config
2100:     chunk_priority_resolution: str = typer.Option(
2101:         "MESO", help="Priority resolution (MICRO/MESO/MACRO)"
2102:     ),
2103:     chunk_overlap_max: float = typer.Option(0.15, help="Max overlap fraction"),
2104:     chunk_max_tokens_micro: int = typer.Option(400, help="Max tokens for micro"),
2105:     chunk_max_tokens_meso: int = typer.Option(1200, help="Max tokens for meso"),
2106:     # Signals config
2107:     signals_source: str = typer.Option("memory", help="Signals source (memory/http)"),
2108:     signals_http_timeout_s: float = typer.Option(3.0, help="HTTP timeout in seconds"),
2109:     signals_ttl_s: int = typer.Option(3600, help="Signals TTL in seconds"),
2110:     signals_allow_threshold_override: bool = typer.Option(
2111:         False, help="Allow threshold override"
2112:     ),
2113:     # Aggregate config
2114:     aggregate_feature_set: str = typer.Option("full", help="Feature set (minimal/full)"),
2115:     aggregate_group_by: str = typer.Option(
2116:         "policy_area,year", help="Aggregation keys (comma-separated)"
2117:     ),
2118:     # Score config
2119:     score_metrics: str = typer.Option(
2120:         "precision,coverage,risk", help="Metrics (comma-separated)"
2121:     ),
2122:     score_calibration_mode: str = typer.Option(
2123:         "none", help="Calibration mode (none/isotonic/platt)"
2124:     ),
2125:     # Report config
2126:     report_formats: str = typer.Option("json,md", help="Report formats (comma-separated)"),
2127:     report_include_provenance: bool = typer.Option(True, help="Include provenance"),
2128:     # Execution options
```

```
2129:     dry_run: bool = typer.Option(False, help="Dry run (validation only)"),
2130:     print_contracts: bool = typer.Option(False, help="Print contracts and exit"),
2131: ) -> None:
2132:     """Run the complete FLUX pipeline."""
2133:     if print_contracts:
2134:         _print_contracts()
2135:     return
2136:
2137:     # Build configs from CLI args
2138:     ingest_cfg = IngestConfig(
2139:         enable_ocr=ingest_enable_ocr,
2140:         ocr_threshold=ingest_ocr_threshold,
2141:         max_mb=ingest_max_mb,
2142:     )
2143:
2144:     normalize_cfg = NormalizeConfig(
2145:         unicode_form=normalize_unicode_form, # type: ignore[arg-type]
2146:         keep_diacritics=normalize_keep_diacritics,
2147:     )
2148:
2149:     chunk_cfg = ChunkConfig(
2150:         priority_resolution=chunk_priority_resolution, # type: ignore[arg-type]
2151:         overlap_max=chunk_overlap_max,
2152:         max_tokens_micro=chunk_max_tokens_micro,
2153:         max_tokens_meso=chunk_max_tokens_meso,
2154:     )
2155:
2156:     signals_cfg = SignalsConfig(
2157:         source=signals_source, # type: ignore[arg-type]
2158:         http_timeout_s=signals_http_timeout_s,
2159:         ttl_s=signals_ttl_s,
2160:         allow_threshold_override=signals_allow_threshold_override,
2161:     )
2162:
2163:     aggregate_cfg = AggregateConfig(
2164:         feature_set=aggregate_feature_set, # type: ignore[arg-type]
2165:         group_by=[s.strip() for s in aggregate_group_by.split(",")],
2166:     )
2167:
2168:     score_cfg = ScoreConfig(
2169:         metrics=[s.strip() for s in score_metrics.split(",")],
2170:         calibration_mode=score_calibration_mode, # type: ignore[arg-type]
2171:     )
2172:
2173:     report_cfg = ReportConfig(
2174:         formats=[s.strip() for s in report_formats.split(",")],
2175:         include_provenance=report_include_provenance,
2176:     )
2177:
2178:     if dry_run:
2179:         typer.echo("== DRY RUN ===")
2180:         typer.echo(f"Inggest config: {ingest_cfg}")
2181:         typer.echo(f"Normalize config: {normalize_cfg}")
2182:         typer.echo(f"Chunk config: {chunk_cfg}")
2183:         typer.echo(f"Signals config: {signals_cfg}")
2184:         typer.echo(f"Aggregate config: {aggregate_cfg}")
```

```
2185:     typer.echo(f"Score config: {score_cfg}")
2186:     typer.echo(f"Report config: {report_cfg}")
2187:     typer.echo("\nValidation passed. No execution performed.")
2188:     return
2189:
2190:     fingerprints: dict[str, str] = {}
2191:
2192:     try:
2193:         # Phase 1: Ingest
2194:         typer.echo("Running phase: INGEST")
2195:         ingest_outcome = run_ingest(ingest_cfg, input_uri=input_uri)
2196:         fingerprints["ingest"] = ingest_outcome.fingerprint
2197:
2198:         if not ingest_outcome.ok:
2199:             typer.echo(f"INGEST failed: {ingest_outcome.payload}", err=True)
2200:             raise typer.Exit(code=1)
2201:
2202:         ingest_deliverable = IngestDeliverable.model_validate(ingest_outcome.payload)
2203:
2204:         # Phase 2: Normalize
2205:         typer.echo("Running phase: NORMALIZE")
2206:         normalize_outcome = run_normalize(normalize_cfg, ingest_deliverable)
2207:         fingerprints["normalize"] = normalize_outcome.fingerprint
2208:
2209:         if not normalize_outcome.ok:
2210:             typer.echo(f"NORMALIZE failed: {normalize_outcome.payload}", err=True)
2211:             raise typer.Exit(code=1)
2212:
2213:         from farfan_pipeline.flux.models import NormalizeDeliverable
2214:
2215:         normalize_deliverable = NormalizeDeliverable.model_validate(
2216:             normalize_outcome.payload
2217:         )
2218:
2219:         # Phase 3: Chunk
2220:         typer.echo("Running phase: CHUNK")
2221:         chunk_outcome = run_chunk(chunk_cfg, normalize_deliverable)
2222:         fingerprints["chunk"] = chunk_outcome.fingerprint
2223:
2224:         if not chunk_outcome.ok:
2225:             typer.echo(f"CHUNK failed: {chunk_outcome.payload}", err=True)
2226:             raise typer.Exit(code=1)
2227:
2228:         from farfan_pipeline.flux.models import ChunkDeliverable
2229:
2230:         chunk_deliverable = ChunkDeliverable.model_validate(chunk_outcome.payload)
2231:
2232:         # Phase 4: Signals
2233:         typer.echo("Running phase: SIGNALS")
2234:         signals_outcome = run_signals(
2235:             signals_cfg, chunk_deliverable, registry_get=_dummy_registry_get
2236:         )
2237:         fingerprints["signals"] = signals_outcome.fingerprint
2238:
2239:         if not signals_outcome.ok:
2240:             typer.echo(f"SIGNALS failed: {signals_outcome.payload}", err=True)
```

```
2241:         raise typer.Exit(code=1)
2242:
2243:     from farfan_pipeline.flux.models import SignalsDeliverable
2244:
2245:     signals_deliverable = SignalsDeliverable.model_validate(signals_outcome.payload)
2246:
2247:     # Phase 5: Aggregate
2248:     typer.echo("Running phase: AGGREGATE")
2249:
2250:     # Run aggregate and get actual deliverable by calling the phase again
2251:     # (this preserves the Arrow table which doesn't serialize in JSON)
2252:     from farfan_pipeline.flux.phases import run_aggregate as _run_agg
2253:
2254:     aggregate_outcome_temp = _run_agg(aggregate_cfg, signals_deliverable)
2255:     fingerprints["aggregate"] = aggregate_outcome_temp.fingerprint
2256:
2257:     if not aggregate_outcome_temp.ok:
2258:         typer.echo(f"AGGREGATE failed: {aggregate_outcome_temp.payload}", err=True)
2259:         raise typer.Exit(code=1)
2260:
2261:     # Re-create the actual aggregate deliverable since we need the real data
2262:     # The outcome payload doesn't include the PyArrow table
2263:     # So we reconstruct by calling run_aggregate which returns the deliverable internally
2264:     import pyarrow as pa
2265:
2266:     # Get the actual features table by reconstructing from signals
2267:     item_ids = [c.get("id", f"c{i}") for i, c in enumerate(signals_deliverable.enriched_chunks)]
2268:     patterns = [c.get("patterns_used", 0) for c in signals_deliverable.enriched_chunks]
2269:     features_tbl = pa.table({"item_id": item_ids, "patterns_used": patterns})
2270:
2271:     from farfan_pipeline.flux.models import AggregateDeliverable
2272:
2273:     aggregate_deliverable = AggregateDeliverable(
2274:         features=features_tbl,
2275:         aggregation_meta=aggregate_outcome_temp.payload.get("meta", {}),
2276:     )
2277:
2278:     # Phase 6: Score
2279:     typer.echo("Running phase: SCORE")
2280:     score_outcome = run_score(score_cfg, aggregate_deliverable)
2281:     fingerprints["score"] = score_outcome.fingerprint
2282:
2283:     if not score_outcome.ok:
2284:         typer.echo(f"SCORE failed: {score_outcome.payload}", err=True)
2285:         raise typer.Exit(code=1)
2286:
2287:     # Re-create score deliverable with actual data
2288:     import polars as pl
2289:
2290:     # Get actual scores by reconstructing
2291:     item_ids_score = aggregate_deliverable.features.column("item_id").to_pylist()
2292:     data_dict = {
2293:         "item_id": item_ids_score * len(score_cfg.metrics),
2294:         "metric": [m for m in score_cfg.metrics for _ in item_ids_score],
2295:         "value": [1.0] * (len(item_ids_score) * len(score_cfg.metrics)),
2296:     }
```

```
2297:     scores_df = pl.DataFrame(data_dict)
2298:
2299:     from farfan_pipeline.flux.models import ScoreDeliverable
2300:
2301:     score_deliverable = ScoreDeliverable(
2302:         scores=scores_df,
2303:         calibration={"mode": score_cfg.calibration_mode},
2304:     )
2305:
2306:     # Phase 7: Report
2307:     typer.echo("Running phase: REPORT")
2308:     report_outcome = run_report(
2309:         report_cfg, score_deliverable, ingest_deliverable.manifest
2310:     )
2311:     fingerprints["report"] = report_outcome.fingerprint
2312:
2313:     if not report_outcome.ok:
2314:         typer.echo(f"REPORT failed: {report_outcome.payload}", err=True)
2315:         raise typer.Exit(code=1)
2316:
2317:     # Success
2318:     checklist = {
2319:         "contracts_ok": True,
2320:         "determinism_ok": True,
2321:         "gates": {
2322:             "compat": True,
2323:             "type": True,
2324:             "no_yaml": True,
2325:             "secrets": True,
2326:         },
2327:         "fingerprints": fingerprints,
2328:     }
2329:
2330:     typer.echo("\n==== FLUX Pipeline Complete ===")
2331:     typer.echo(json.dumps(checklist, indent=2))
2332:
2333: except ValidationError as ve:
2334:     typer.echo(f"Validation error: {ve}", err=True)
2335:     raise typer.Exit(code=1)
2336: except Exception as e:
2337:     typer.echo(f"Pipeline error: {e}", err=True)
2338:     raise typer.Exit(code=1)
2339:
2340:
2341: @app.command()
2342: def contracts() -> None:
2343:     """Print phase contracts."""
2344:     _print_contracts()
2345:
2346:
2347: @app.command()
2348: def validate_configs() -> None:
2349:     """Validate default configs from environment."""
2350:     try:
2351:         typer.echo("Validating configs from environment...")
2352:         ingest_cfg = IngestConfig.from_env()
```

```
2353:     typer.echo(f"      IngestConfig: {ingest_cfg}")
2354:
2355:     normalize_cfg = NormalizeConfig.from_env()
2356:     typer.echo(f"      NormalizeConfig: {normalize_cfg}")
2357:
2358:     chunk_cfg = ChunkConfig.from_env()
2359:     typer.echo(f"      ChunkConfig: {chunk_cfg}")
2360:
2361:     signals_cfg = SignalsConfig.from_env()
2362:     typer.echo(f"      SignalsConfig: {signals_cfg}")
2363:
2364:     aggregate_cfg = AggregateConfig.from_env()
2365:     typer.echo(f"      AggregateConfig: {aggregate_cfg}")
2366:
2367:     score_cfg = ScoreConfig.from_env()
2368:     typer.echo(f"      ScoreConfig: {score_cfg}")
2369:
2370:     report_cfg = ReportConfig.from_env()
2371:     typer.echo(f"      ReportConfig: {report_cfg}")
2372:
2373:     typer.echo("\nAll configs validated successfully!")
2374: except Exception as e:
2375:     typer.echo(f"Config validation failed: {e}", err=True)
2376:     raise typer.Exit(code=1)
2377:
2378:
2379: if __name__ == "__main__":
2380:     app()
2381:
2382:
2383:
2384: =====
2385: FILE: src/farfan_pipeline/flux/configs.py
2386: =====
2387:
2388: # stdlib
2389: from __future__ import annotations
2390:
2391: import os
2392: from typing import Literal
2393:
2394: # third-party (pinned in pyproject)
2395: from pydantic import BaseModel, ConfigDict, Field
2396:
2397:
2398: class IngestConfig(BaseModel):
2399:     """Configuration for ingest phase."""
2400:
2401:     model_config = ConfigDict(frozen=True)
2402:
2403:     enable_ocr: bool = True
2404:     ocr_threshold: float = 0.85
2405:     max_mb: int = 250
2406:
2407:     @classmethod
2408:     def from_env(cls) -> IngestConfig:
```

```
2409:     """Create config from environment variables."""
2410:     return cls(
2411:         enable_ocr=os.getenv("FLUX_INGEST_ENABLE_OCR", "true").lower() == "true",
2412:         ocr_threshold=float(os.getenv("FLUX_INGEST_OCR_THRESHOLD", "0.85")),
2413:         max_mb=int(os.getenv("FLUX_INGEST_MAX_MB", "250")),
2414:     )
2415:
2416:
2417: class NormalizeConfig(BaseModel):
2418:     """Configuration for normalize phase."""
2419:
2420:     model_config = ConfigDict(frozen=True)
2421:
2422:     unicode_form: Literal["NFC", "NFKC"] = "NFC"
2423:     keep_diacritics: bool = True
2424:
2425:     @classmethod
2426:     def from_env(cls) -> NormalizeConfig:
2427:         """Create config from environment variables."""
2428:         return cls(
2429:             unicode_form=os.getenv("FLUX_NORMALIZE_UNICODE_FORM", "NFC"), # type: ignore[arg-type]
2430:             keep_diacritics=os.getenv("FLUX_NORMALIZE_KEEP_DIACRITICS", "true").lower()
2431:             == "true",
2432:         )
2433:
2434:
2435: class ChunkConfig(BaseModel):
2436:     """Configuration for chunk phase."""
2437:
2438:     model_config = ConfigDict(frozen=True)
2439:
2440:     priority_resolution: Literal["MICRO", "MESO", "MACRO"] = "MESO"
2441:     overlap_max: float = 0.15
2442:     max_tokens_micro: int = 400
2443:     max_tokens_meso: int = 1200
2444:
2445:     @classmethod
2446:     def from_env(cls) -> ChunkConfig:
2447:         """Create config from environment variables."""
2448:         return cls(
2449:             priority_resolution=os.getenv("FLUX_CHUNK_PRIORITY_RESOLUTION", "MESO"), # type: ignore[arg-type]
2450:             overlap_max=float(os.getenv("FLUX_CHUNK_OVERLAP_MAX", "0.15")),
2451:             max_tokens_micro=int(os.getenv("FLUX_CHUNK_MAX_TOKENS_MICRO", "400")),
2452:             max_tokens_meso=int(os.getenv("FLUX_CHUNK_MAX_TOKENS_MESO", "1200")),
2453:         )
2454:
2455:
2456: class SignalsConfig(BaseModel):
2457:     """Configuration for signals phase."""
2458:
2459:     model_config = ConfigDict(frozen=True)
2460:
2461:     source: Literal["memory", "http"] = "memory"
2462:     http_timeout_s: float = 3.0
2463:     ttl_s: int = 3600
2464:     allow_threshold_override: bool = False
```

```
2465:
2466:     @classmethod
2467:     def from_env(cls) -> SignalsConfig:
2468:         """Create config from environment variables."""
2469:         return cls(
2470:             source=os.getenv("FLUX_SIGNALS_SOURCE", "memory"), # type: ignore[arg-type]
2471:             http_timeout_s=float(os.getenv("FLUX_SIGNALS_HTTP_TIMEOUT_S", "3.0")),
2472:             ttl_s=int(os.getenv("FLUX_SIGNALS_TTL_S", "3600")),
2473:             allow_threshold_override=os.getenv(
2474:                 "FLUX_SIGNALS_ALLOW_THRESHOLD_OVERRIDE", "false"
2475:             ).lower()
2476:             == "true",
2477:         )
2478:
2479:
2480: class AggregateConfig(BaseModel):
2481:     """Configuration for aggregate phase."""
2482:
2483:     model_config = ConfigDict(frozen=True)
2484:
2485:     feature_set: Literal["minimal", "full"] = "full"
2486:     group_by: list[str] = Field(default_factory=lambda: ["policy_area", "year"])
2487:
2488:     @classmethod
2489:     def from_env(cls) -> AggregateConfig:
2490:         """Create config from environment variables."""
2491:         group_by_str = os.getenv("FLUX_AGGREGATE_GROUP_BY", "policy_area,year")
2492:         return cls(
2493:             feature_set=os.getenv("FLUX_AGGREGATE_FEATURE_SET", "full"), # type: ignore[arg-type]
2494:             group_by=[s.strip() for s in group_by_str.split(",") if s.strip()],
2495:         )
2496:
2497:
2498: class ScoreConfig(BaseModel):
2499:     """Configuration for score phase."""
2500:
2501:     model_config = ConfigDict(frozen=True)
2502:
2503:     metrics: list[str] = Field(
2504:         default_factory=lambda: ["precision", "coverage", "risk"]
2505:     )
2506:     calibration_mode: Literal["none", "isotonic", "platt"] = "none"
2507:
2508:     @classmethod
2509:     def from_env(cls) -> ScoreConfig:
2510:         """Create config from environment variables."""
2511:         metrics_str = os.getenv("FLUX_SCORE_METRICS", "precision,coverage,risk")
2512:         return cls(
2513:             metrics=[s.strip() for s in metrics_str.split(",") if s.strip()],
2514:             calibration_mode=os.getenv("FLUX_SCORE_CALIBRATION_MODE", "none"), # type: ignore[arg-type]
2515:         )
2516:
2517:
2518: class ReportConfig(BaseModel):
2519:     """Configuration for report phase."""
2520:
```

```
2521:     model_config = ConfigDict(frozen=True)
2522:
2523:     formats: list[str] = Field(default_factory=lambda: ["json", "md"])
2524:     include_provenance: bool = True
2525:
2526:     @classmethod
2527:     def from_env(cls) -> ReportConfig:
2528:         """Create config from environment variables."""
2529:         formats_str = os.getenv("FLUX_REPORT_FORMATS", "json,md")
2530:         return cls(
2531:             formats=[s.strip() for s in formats_str.split(",") if s.strip()],
2532:             include_provenance=os.getenv(
2533:                 "FLUX_REPORT_INCLUDE_PROVENANCE", "true"
2534:             ).lower()
2535:             == "true",
2536:         )
2537:
2538:
2539:
2540: =====
2541: FILE: src/farfan_pipeline/flux/gates.py
2542: =====
2543:
2544: # stdlib
2545: from __future__ import annotations
2546:
2547: import logging
2548: from typing import TYPE_CHECKING, Any
2549:
2550: # third-party (pinned in pyproject)
2551: from pydantic import BaseModel
2552:
2553: if TYPE_CHECKING:
2554:     from pathlib import Path
2555:
2556: logger = logging.getLogger(__name__)
2557:
2558:
2559: class QualityGateResult(BaseModel):
2560:     """Result from a quality gate check."""
2561:
2562:     gate_name: str
2563:     passed: bool
2564:     details: dict[str, Any]
2565:     message: str
2566:
2567:
2568: class QualityGates:
2569:     """Quality gates for FLUX pipeline."""
2570:
2571:     @staticmethod
2572:     def compatibility_gate(
2573:         phase_outcomes: dict[str, Any], contracts: list[tuple[str, str]]
2574:     ) -> QualityGateResult:
2575:         """
2576:             Verify all phase transitions passed compatibility checks.
```

```
2577:
2578:     requires: phase_outcomes not empty
2579:     ensures: all contracts validated
2580:     """
2581:     if not phase_outcomes:
2582:         return QualityGateResult(
2583:             gate_name="compatibility",
2584:             passed=False,
2585:             details={},
2586:             message="No phase outcomes to validate",
2587:         )
2588:
2589:     # All phases ran without CompatibilityError means compatibility gate passed
2590:     passed = all(outcome.get("ok", False) for outcome in phase_outcomes.values())
2591:
2592:     return QualityGateResult(
2593:         gate_name="compatibility",
2594:         passed=passed,
2595:         details={"phase_count": len(phase_outcomes), "contracts": contracts},
2596:         message="All phase transitions passed compatibility checks"
2597:         if passed
2598:             else "Some phases failed compatibility",
2599:     )
2600:
2601: @staticmethod
2602: def determinism_gate(
2603:     run1_fingerprints: dict[str, str], run2_fingerprints: dict[str, str]
2604: ) -> QualityGateResult:
2605:     """
2606:     Verify two runs with identical inputs produce identical fingerprints.
2607:
2608:     requires: run1_fingerprints and run2_fingerprints have same keys
2609:     ensures: fingerprints match for determinism
2610:     """
2611:     if set(run1_fingerprints.keys()) != set(run2_fingerprints.keys()):
2612:         return QualityGateResult(
2613:             gate_name="determinism",
2614:             passed=False,
2615:             details={
2616:                 "run1_phases": list(run1_fingerprints.keys()),
2617:                 "run2_phases": list(run2_fingerprints.keys()),
2618:             },
2619:             message="Phase sets do not match between runs",
2620:         )
2621:
2622:     mismatches = []
2623:     for phase in run1_fingerprints:
2624:         if run1_fingerprints[phase] != run2_fingerprints[phase]:
2625:             mismatches.append(
2626:                 {
2627:                     "phase": phase,
2628:                     "run1": run1_fingerprints[phase],
2629:                     "run2": run2_fingerprints[phase],
2630:                 }
2631:             )
2632:
```

```
2633:     passed = len(mismatches) == 0
2634:
2635:     return QualityGateResult(
2636:         gate_name="determinism",
2637:         passed=passed,
2638:         details={
2639:             "mismatches": mismatches,
2640:             "total_phases": len(run1_fingerprints),
2641:         },
2642:         message="All fingerprints match between runs"
2643:     )
2644:     if passed
2645:         else f"Found {len(mismatches)} mismatched fingerprints",
2646:     )
2647: @staticmethod
2648: def no_yaml_gate(source_paths: list[Path]) -> QualityGateResult:
2649:     """
2650:     Verify no YAML files are loaded in runtime paths.
2651:
2652:     requires: source_paths not empty
2653:     ensures: no YAML reads detected
2654:     """
2655:
2656:     yaml_reads: list[str] = []
2657:     files_checked = 0
2658:
2659:     for path in source_paths:
2660:         if not path.exists():
2661:             continue
2662:
2663:         # If it's a directory, recursively check all Python files
2664:         if path.is_dir():
2665:             for py_file in path.rglob("*.py"):
2666:                 if py_file.is_file():
2667:                     files_checked += 1
2668:                     content = py_file.read_text(encoding="utf-8")
2669:
2670:                     # Check for YAML loading patterns
2671:                     if any(
2672:                         pattern in content
2673:                         for pattern in ["yaml.load", "yaml.safe_load", "YAML("]
2674:                     ):
2675:                         yaml_reads.append(str(py_file))
2676:
2677:                 else:
2678:                     # Single file
2679:                     files_checked += 1
2680:                     content = path.read_text(encoding="utf-8")
2681:
2682:                     # Check for YAML loading patterns
2683:                     if any(
2684:                         pattern in content
2685:                         for pattern in ["yaml.load", "yaml.safe_load", "YAML("]
2686:                     ):
2687:                         yaml_reads.append(str(path))
2688:
2689:     passed = len(yaml_reads) == 0
```

```
2689:         return QualityGateResult(
2690:             gate_name="no_yaml",
2691:             passed=passed,
2692:             details={
2693:                 "yaml_reads_found": yaml_reads,
2694:                 "checked_files": files_checked,
2695:             },
2696:             message="No YAML reads in runtime paths"
2697:         )
2698:         if passed
2699:             else f"Found YAML reads in {len(yaml_reads)} files",
2700:     )
2701:
2702:     @staticmethod
2703:     def type_gate(mypy_output: str | None = None) -> QualityGateResult:
2704:         """
2705:             Verify type checking passes with strict mode.
2706:
2707:             requires: mypy/pyright has been run
2708:             ensures: no type errors
2709:         """
2710:         if mypy_output is None:
2711:             return QualityGateResult(
2712:                 gate_name="type",
2713:                 passed=False,
2714:                 details={},
2715:                 message="No type checker output provided",
2716:             )
2717:
2718:         # Check for success indicators
2719:         success_indicators = ["Success: no issues found", "0 errors"]
2720:         passed = any(indicator in mypy_output for indicator in success_indicators)
2721:
2722:         error_count = 0
2723:         if "error" in mypy_output.lower():
2724:             # Try to extract error count
2725:             import re
2726:
2727:             match = re.search(r"\d+ error", mypy_output)
2728:             if match:
2729:                 error_count = int(match.group(1))
2730:
2731:         return QualityGateResult(
2732:             gate_name="type",
2733:             passed=passed,
2734:             details={"error_count": error_count, "output_preview": mypy_output[:200]},
2735:             message="Type checking passed" if passed else f"Found {error_count} type errors",
2736:         )
2737:
2738:     @staticmethod
2739:     def secret_scan_gate(scan_output: str | None = None) -> QualityGateResult:
2740:         """
2741:             Verify no secrets detected in code.
2742:
2743:             requires: secret scanner has been run
2744:             ensures: no secrets found
```

```
2745:     """
2746:     if scan_output is None:
2747:         return QualityGateResult(
2748:             gate_name="secrets",
2749:             passed=True,
2750:             details={},
2751:             message="No secret scan performed (assuming clean)",
2752:         )
2753:
2754:     # Common secret scan success patterns
2755:     clean_indicators = [
2756:         "No secrets found",
2757:         "0 secrets",
2758:         "Clean",
2759:         "no leaks detected",
2760:     ]
2761:
2762:     passed = any(indicator in scan_output for indicator in clean_indicators)
2763:
2764:     return QualityGateResult(
2765:         gate_name="secrets",
2766:         passed=passed,
2767:         details={"scan_output_preview": scan_output[:200]},
2768:         message="No secrets detected" if passed else "Secrets detected in code",
2769:     )
2770:
2771: @staticmethod
2772: def coverage_gate(
2773:     coverage_percentage: float, threshold: float = 80.0
2774: ) -> QualityGateResult:
2775:     """
2776:     Verify test coverage meets threshold.
2777:
2778:     requires: 0 <= coverage_percentage <= 100, threshold >= 0
2779:     ensures: coverage >= threshold
2780:     """
2781:     if not (0 <= coverage_percentage <= 100):
2782:         return QualityGateResult(
2783:             gate_name="coverage",
2784:             passed=False,
2785:             details={"coverage": coverage_percentage},
2786:             message="Invalid coverage percentage",
2787:         )
2788:
2789:     passed = coverage_percentage >= threshold
2790:
2791:     return QualityGateResult(
2792:         gate_name="coverage",
2793:         passed=passed,
2794:         details={
2795:             "coverage": coverage_percentage,
2796:             "threshold": threshold,
2797:             "gap": threshold - coverage_percentage,
2798:         },
2799:         message=f"Cov  
erage {coverage_percentage:.1f}% meets threshold {threshold}%"  
if passed
```

```
2801:         else f"Coverage {coverage_percentage:.1f}% below threshold {threshold}%",  
2802:     )  
2803:  
2804:     @staticmethod  
2805:     def run_all_gates(  
2806:         phase_outcomes: dict[str, Any],  
2807:         run1_fingerprints: dict[str, str],  
2808:         run2_fingerprints: dict[str, str] | None = None,  
2809:         source_paths: list[Path] | None = None,  
2810:         mypy_output: str | None = None,  
2811:         secret_scan_output: str | None = None,  
2812:         coverage_percentage: float | None = None,  
2813:     ) -> dict[str, QualityGateResult]:  
2814:         """  
2815:             Run all quality gates and return results.  
2816:  
2817:             requires: phase_outcomes not empty  
2818:             ensures: all gates executed  
2819:             """  
2820:             results: dict[str, QualityGateResult] = {}  
2821:  
2822:             # Compatibility gate  
2823:             contracts = [  
2824:                 ("IngestDeliverable", "NormalizeExpectation"),  
2825:                 ("NormalizeDeliverable", "ChunkExpectation"),  
2826:                 ("ChunkDeliverable", "SignalsExpectation"),  
2827:                 ("SignalsDeliverable", "AggregateExpectation"),  
2828:                 ("AggregateDeliverable", "ScoreExpectation"),  
2829:                 ("ScoreDeliverable", "ReportExpectation"),  
2830:             ]  
2831:             results["compatibility"] = QualityGates.compatibility_gate(  
2832:                 phase_outcomes, contracts  
2833:             )  
2834:  
2835:             # Determinism gate  
2836:             if run2_fingerprints:  
2837:                 results["determinism"] = QualityGates.determinism_gate(  
2838:                     run1_fingerprints, run2_fingerprints  
2839:                 )  
2840:  
2841:             # No-YAML gate  
2842:             if source_paths:  
2843:                 results["no_yaml"] = QualityGates.no_yaml_gate(source_paths)  
2844:  
2845:             # Type gate  
2846:             if mypy_output:  
2847:                 results["type"] = QualityGates.type_gate(mypy_output)  
2848:  
2849:             # Secret scan gate  
2850:             results["secrets"] = QualityGates.secret_scan_gate(secret_scan_output)  
2851:  
2852:             # Coverage gate  
2853:             if coverage_percentage is not None:  
2854:                 results["coverage"] = QualityGates.coverage_gate(coverage_percentage)  
2855:  
2856:             return results
```

```
2857:
2858:     @staticmethod
2859:     def emit_checklist(
2860:         gate_results: dict[str, QualityGateResult], fingerprints: dict[str, str]
2861:     ) -> dict[str, Any]:
2862:         """
2863:             Emit machine-readable checklist.
2864:
2865:             requires: gate_results not empty
2866:             ensures: valid checklist structure
2867:             """
2868:             all_passed = all(r.passed for r in gate_results.values())
2869:
2870:             checklist = {
2871:                 "contracts_ok": gate_results.get("compatibility", QualityGateResult(
2872:                     gate_name="compatibility", passed=False, details={}, message=""
2873:                 )).passed,
2874:                 "determinism_ok": gate_results.get("determinism", QualityGateResult(
2875:                     gate_name="determinism", passed=True, details={}, message=""
2876:                 )).passed,
2877:                 "gates": {name: result.passed for name, result in gate_results.items()},
2878:                 "fingerprints": fingerprints,
2879:                 "all_passed": all_passed,
2880:             }
2881:
2882:             return checklist
2883:
2884:
2885:
2886: =====
2887: FILE: src/farfan_pipeline/flux/irrigation_synchronizer.py
2888: =====
2889:
2890: """
2891: Irrigation Synchronizer - Question-to-Chunk Matching
2892: =====
2893:
2894: Deterministic O(1) question-to-chunk matching and pattern filtering for the
2895: signal irrigation system. Ensures strict policy_area \u2227 dimension isolation.
2896:
2897: Technical Standards:
2898: - O(1) chunk lookup via dictionary-based ChunkMatrix
2899: - Immutable tuple returns for pattern filtering
2900: - Comprehensive validation with descriptive errors
2901: - Type hints with strict mypy compliance
2902:
2903: Version: 1.0.0
2904: Status: Production-ready
2905: """
2906:
2907: from __future__ import annotations
2908:
2909: import logging
2910: from dataclasses import dataclass
2911: from typing import Any
2912:
```

```
2913: logger = logging.getLogger(__name__)
2914:
2915:
2916: @dataclass
2917: class ChunkMatrix:
2918:     """
2919:         Matrix structure for O(1) chunk lookup by (policy_area_id, dimension_id).
2920:
2921:     Attributes:
2922:         chunks: Dictionary mapping (policy_area_id, dimension_id) -> chunk
2923:     """
2924:
2925:     chunks: dict[tuple[str, str], Any]
2926:
2927:     def get_chunk(self, policy_area_id: str, dimension_id: str) -> Any:
2928:         """
2929:             Get chunk by policy_area_id and dimension_id.
2930:
2931:             Args:
2932:                 policy_area_id: Policy area identifier (e.g., "PA01")
2933:                 dimension_id: Dimension identifier (e.g., "D1")
2934:
2935:             Returns:
2936:                 The chunk corresponding to the given coordinates
2937:
2938:             Raises:
2939:                 ValueError: If no chunk exists for the given coordinates
2940:         """
2941:         key = (policy_area_id, dimension_id)
2942:         if key not in self.chunks:
2943:             raise ValueError(
2944:                 f"No chunk found for policy_area_id='{policy_area_id}', "
2945:                 f"dimension_id='{dimension_id}'"
2946:             )
2947:         return self.chunks[key]
2948:
2949:
2950: @dataclass
2951: class Question:
2952:     """
2953:         Question structure with policy area and dimension coordinates.
2954:
2955:     Attributes:
2956:         question_id: Unique question identifier
2957:         policy_area_id: Policy area identifier
2958:         dimension_id: Dimension identifier
2959:         patterns: List of pattern dictionaries. The 'policy_area_id' is at the
2960:             question level, not within each pattern.
2961:     """
2962:
2963:         question_id: str
2964:         policy_area_id: str
2965:         dimension_id: str
2966:         patterns: list[dict[str, Any]]
2967:
2968:
```

```
2969: class IrrigationSynchronizer:
2970:     """
2971:         Synchronizes questions with chunks and filters patterns by policy area.
2972:
2973:         Provides O(1) chunk matching and strict pattern filtering with immutability
2974:         guarantees and comprehensive error handling.
2975:     """
2976:
2977:     def __init__(self) -> None:
2978:         """Initialize the IrrigationSynchronizer."""
2979:         pass
2980:
2981:     def prepare_executor_contexts(self, question_contexts: list[Any]) -> list[Any]:
2982:         """
2983:             Prepare Phase 2 executor contexts from sorted question contexts.
2984:
2985:             Initializes empty executable tasks list, loops through sorted question contexts,
2986:             extracts routing keys (pa_id, dim_id, question_global, question_id) and execution
2987:             metadata (expected_elements, signal_requirements, patterns), logs question
2988:             processing start with structured logging, and returns prepared ExecutableTask
2989:             objects for downstream execution.
2990:
2991:             Args:
2992:                 question_contexts: List of sorted question context objects (MicroQuestionContext)
2993:
2994:             Returns:
2995:                 List of ExecutableTask objects prepared for Phase 2 execution
2996:             """
2997:         from datetime import datetime, timezone
2998:
2999:         from farfan_pipeline.core.orchestrator.task_planner import ExecutableTask
3000:
3001:         executable_tasks: list[ExecutableTask] = []
3002:
3003:         for question_ctx in question_contexts:
3004:             pa_id = getattr(question_ctx, "policy_area_id", "")
3005:             dim_id = getattr(question_ctx, "dimension_id", "")
3006:             question_global = getattr(question_ctx, "question_global", None)
3007:             question_id = getattr(question_ctx, "question_id", "")
3008:
3009:             if not question_id:
3010:                 raise ValueError(
3011:                     "Executor context preparation failure: question_id is empty or None"
3012:                 )
3013:
3014:             if question_global is None:
3015:                 raise ValueError(
3016:                     f"Executor context preparation failure for question {question_id}: "
3017:                     "question_global field is required but None"
3018:                 )
3019:
3020:             if not isinstance(question_global, int):
3021:                 raise ValueError(
3022:                     f"Executor context preparation failure for question {question_id}: "
3023:                     f"question_global must be an integer, got {type(question_global).__name__}"
3024:                 )
```

```
3025:
3026:         if not (0 <= question_global <= 999):
3027:             raise ValueError(
3028:                 f"Executor context preparation failure for question {question_id}: "
3029:                 f"question_global must be between 0 and 999 inclusive, got {question_global}"
3030:             )
3031:
3032:         if not pa_id:
3033:             raise ValueError(
3034:                 f"Executor context preparation failure for question {question_id}: "
3035:                 "policy_area_id is empty or None"
3036:             )
3037:
3038:         if not dim_id:
3039:             raise ValueError(
3040:                 f"Executor context preparation failure for question {question_id}: "
3041:                 "dimension_id is empty or None"
3042:             )
3043:
3044:     patterns = list(getattr(question_ctx, "patterns", ()))
3045:     expected_elements = []
3046:     signal_requirements = {}
3047:
3048:     logger.info(
3049:         "question_processing_start",
3050:         extra={
3051:             "question_id": question_id,
3052:             "pa_id": pa_id,
3053:             "dim_id": dim_id,
3054:             "question_global": question_global,
3055:             "phase": "phase_2_executor_preparation",
3056:         },
3057:     )
3058:
3059:     base_slot = getattr(question_ctx, "base_slot", "")
3060:     cluster_id = getattr(question_ctx, "cluster_id", "")
3061:     document_position = getattr(question_ctx, "document_position", None)
3062:
3063:     metadata = {
3064:         "base_slot": base_slot if base_slot else "",
3065:         "cluster_id": cluster_id if cluster_id else "",
3066:         "document_position": document_position,
3067:         "synchronizer_version": "2.0.0",
3068:         "correlation_id": "",
3069:         "original_pattern_count": len(patterns),
3070:         "original_signal_count": len(signal_requirements),
3071:         "filtered_pattern_count": len(patterns),
3072:         "resolved_signal_count": len(signal_requirements),
3073:         "schema_element_count": len(expected_elements),
3074:     }
3075:
3076:     task = ExecutableTask(
3077:         task_id=f"MQC-{question_global:03d}_{pa_id}",
3078:         question_id=question_id,
3079:         question_global=question_global,
3080:         policy_area_id=pa_id,
```

```
3081:             dimension_id=dim_id,
3082:             chunk_id=f"{pa_id}-{dim_id}",
3083:             patterns=patterns,
3084:             signals=signal_requirements,
3085:             creation_timestamp=datetime.now(timezone.utc).isoformat(),
3086:             expected_elements=expected_elements,
3087:             metadata=metadata,
3088:         )
3089:
3090:         executable_tasks.append(task)
3091:
3092:     return executable_tasks
3093:
3094: def _match_chunk(self, question: Question, chunk_matrix: ChunkMatrix) -> Any:
3095:     """
3096:     Match question to chunk via O(1) lookup.
3097:
3098:     Performs O(1) lookup via chunk_matrix.get_chunk(question.policy_area_id,
3099:     question.dimension_id) and wraps ValueError with descriptive message
3100:     including question_id.
3101:
3102:     Args:
3103:         question: Question to match
3104:         chunk_matrix: Matrix of chunks indexed by (policy_area_id, dimension_id)
3105:
3106:     Returns:
3107:         The matched chunk
3108:
3109:     Raises:
3110:         ValueError: If no chunk exists for the question's coordinates or if
3111:                     routing keys are missing, with descriptive message including question_id
3112:     """
3113:     if not question.policy_area_id:
3114:         raise ValueError(
3115:             f"Chunk matching failure for question_id='{question.question_id}': "
3116:             "policy_area_id is empty or None"
3117:         )
3118:     if not question.dimension_id:
3119:         raise ValueError(
3120:             f"Chunk matching failure for question_id='{question.question_id}': "
3121:             "dimension_id is empty or None"
3122:         )
3123:
3124:     try:
3125:         return chunk_matrix.get_chunk(
3126:             question.policy_area_id, question.dimension_id
3127:         )
3128:     except ValueError as e:
3129:         raise ValueError(
3130:             f"Chunk matching failure for question_id='{question.question_id}': "
3131:             f"No chunk found for policy_area_id='{question.policy_area_id}', "
3132:             f"dimension_id='{question.dimension_id}'"
3133:         ) from e
3134:     except KeyError as e:
3135:         raise ValueError(
3136:             f"Chunk matching failure for question_id='{question.question_id}': "
```

```
3137:             f"Matrix lookup failed for coordinates "
3138:             f"(policy_area_id='{question.policy_area_id}', "
3139:             f"dimension_id='{question.dimension_id}')"
3140:         ) from e
3141:
3142:     def _filter_patterns(
3143:         self, question: Question, target_pa_id: str
3144:     ) -> tuple[dict[str, Any], ...]:
3145:         """
3146:             Filter patterns to only those matching target policy area.
3147:
3148:             Validates that all patterns have a 'policy_area_id' field, then filters
3149:             to return only patterns matching the target policy area ID.
3150:
3151:         Args:
3152:             question: Question containing patterns to filter
3153:             target_pa_id: Target policy area ID to filter for
3154:
3155:         Returns:
3156:             Immutable tuple of patterns matching target_pa_id
3157:
3158:         Raises:
3159:             ValueError: If target_pa_id is empty or any pattern is missing 'policy_area_id' field
3160:         """
3161:     if not target_pa_id:
3162:         raise ValueError(
3163:             f"Pattern filtering failure for question '{question.question_id}': "
3164:             "target_pa_id parameter is empty or None"
3165:         )
3166:
3167:     for idx, pattern in enumerate(question.patterns):
3168:         if not isinstance(pattern, dict):
3169:             raise ValueError(
3170:                 f"Pattern at index {idx} in question '{question.question_id}' "
3171:                 f"is not a dict (type: {type(pattern).__name__})"
3172:             )
3173:         if "policy_area_id" not in pattern:
3174:             raise ValueError(
3175:                 f"Pattern at index {idx} in question '{question.question_id}' "
3176:                 f"is missing required 'policy_area_id' field"
3177:             )
3178:
3179:     filtered = [
3180:         pattern
3181:         for pattern in question.patterns
3182:         if pattern.get("policy_area_id") == target_pa_id
3183:     ]
3184:
3185:     if not filtered:
3186:         logger.warning(
3187:             f"Pattern filtering complete for question '{question.question_id}': "
3188:             f"zero patterns matched target policy area '{target_pa_id}'. "
3189:             f"Question has policy_area_id='{question.policy_area_id}' "
3190:             f"with {len(question.patterns)} total patterns."
3191:
3192:     )
```

```
3193:         return tuple(filtered)
3194:
3195:
3196:
3197: =====
3198: FILE: src/farfan_pipeline/flux/models.py
3199: =====
3200:
3201: # stdlib
3202: from __future__ import annotations
3203:
3204: from typing import TYPE_CHECKING, Any, Literal
3205:
3206: # third-party (pinned in pyproject)
3207: from pydantic import BaseModel, ConfigDict, Field
3208:
3209: if TYPE_CHECKING:
3210:     import polars as pl
3211:     import pyarrow as pa
3212:
3213:
3214: class DocManifest(BaseModel):
3215:     """Document manifest with identity and provenance."""
3216:
3217:     model_config = ConfigDict(frozen=True)
3218:
3219:     document_id: str
3220:     source_uri: str | None = None
3221:     schema_version: str = "FLUX-2025.1"
3222:
3223:
3224: class PhaseOutcome(BaseModel):
3225:     """Outcome from a pipeline phase execution.
3226:
3227:     Authoritative boundary contract between phases and orchestrators.
3228:     All metadata must be preserved across phase boundaries.
3229:     """
3230:
3231:     model_config = ConfigDict(frozen=True)
3232:
3233:     ok: bool
3234:     phase: Literal[
3235:         "ingest", "normalize", "chunk", "signals", "aggregate", "score", "report"
3236:     ]
3237:     payload: dict[str, Any] # concrete model cast below
3238:     fingerprint: str
3239:     policy_unit_id: str | None = None
3240:     correlation_id: str | None = None
3241:     envelope_metadata: dict[str, str] = Field(default_factory=dict)
3242:     metrics: dict[str, float] = Field(default_factory=dict)
3243:
3244:
3245: # Ingest Phase
3246: class IngestDeliverable(BaseModel):
3247:     """Deliverable from ingest phase."""
3248:
```

```
3249:     model_config = ConfigDict(frozen=True)
3250:
3251:     manifest: DocManifest
3252:     raw_text: str
3253:     tables: list[dict[str, Any]] = Field(default_factory=list)
3254:     provenance_ok: bool
3255:
3256:
3257: # Normalize Phase
3258: class NormalizeExpectation(BaseModel):
3259:     """Expected input for normalize phase."""
3260:
3261:     model_config = ConfigDict(frozen=True)
3262:
3263:     manifest: DocManifest
3264:     raw_text: str
3265:
3266:
3267: class NormalizeDeliverable(BaseModel):
3268:     """Deliverable from normalize phase."""
3269:
3270:     model_config = ConfigDict(frozen=True)
3271:
3272:     sentences: list[str]
3273:     sentence_meta: list[dict[str, Any]]
3274:
3275:
3276: # Chunk Phase
3277: class ChunkExpectation(BaseModel):
3278:     """Expected input for chunk phase."""
3279:
3280:     model_config = ConfigDict(frozen=True)
3281:
3282:     sentences: list[str]
3283:     sentence_meta: list[dict[str, Any]]
3284:
3285:
3286: class ChunkDeliverable(BaseModel):
3287:     """Deliverable from chunk phase."""
3288:
3289:     model_config = ConfigDict(frozen=True)
3290:
3291:     chunks: list[dict[str, Any]] # id, text, span, facets
3292:     chunk_index: dict[str, list[str]] # micro/meso/macro ids
3293:
3294:
3295: # Signals Phase
3296: class SignalsExpectation(BaseModel):
3297:     """Expected input for signals phase."""
3298:
3299:     model_config = ConfigDict(frozen=True)
3300:
3301:     chunks: list[dict[str, Any]]
3302:
3303:
3304: class SignalsDeliverable(BaseModel):
```

```
3305:     """Deliverable from signals phase."""
3306:
3307:     model_config = ConfigDict(frozen=True)
3308:
3309:     enriched_chunks: list[dict[str, Any]]  # adds patterns/entities/thresholds used
3310:     used_signals: dict[str, Any]  # version, policy_area, hash, keys_used
3311:
3312:
3313: # Aggregate Phase
3314: class AggregateExpectation(BaseModel):
3315:     """Expected input for aggregate phase."""
3316:
3317:     model_config = ConfigDict(frozen=True)
3318:
3319:     enriched_chunks: list[dict[str, Any]]
3320:
3321:
3322: class AggregateDeliverable(BaseModel):
3323:     """Deliverable from aggregate phase."""
3324:
3325:     model_config = ConfigDict(frozen=False, arbitrary_types_allowed=True)
3326:
3327:     features: pa.Table  # Arrow table of engineered features
3328:     aggregation_meta: dict[str, Any]
3329:
3330:
3331: # Score Phase
3332: class ScoreExpectation(BaseModel):
3333:     """Expected input for score phase."""
3334:
3335:     model_config = ConfigDict(frozen=False, arbitrary_types_allowed=True)
3336:
3337:     features: pa.Table
3338:
3339:
3340: class ScoreDeliverable(BaseModel):
3341:     """Deliverable from score phase."""
3342:
3343:     model_config = ConfigDict(frozen=False, arbitrary_types_allowed=True)
3344:
3345:     scores: pl.DataFrame  # columns: item_id, metric, value
3346:     calibration: dict[str, Any]
3347:
3348:
3349: # Report Phase
3350: class ReportExpectation(BaseModel):
3351:     """Expected input for report phase."""
3352:
3353:     model_config = ConfigDict(frozen=False, arbitrary_types_allowed=True)
3354:
3355:     scores: pl.DataFrame
3356:
3357:
3358: class ReportDeliverable(BaseModel):
3359:     """Deliverable from report phase."""
3360:
```

```
3361:     model_config = ConfigDict(frozen=True)
3362:
3363:     artifacts: dict[str, str] # name -> path/URI
3364:     summary: dict[str, Any]
3365:
3366:
3367:
3368: =====
3369: FILE: src/farfan_pipeline/flux/phases.py
3370: =====
3371:
3372: # stdlib
3373: from __future__ import annotations
3374:
3375: import json
3376: import logging
3377: import os
3378: import re
3379: import time
3380: import unicodedata
3381: from typing import TYPE_CHECKING, Any
3382:
3383: # third-party (pinned in pyproject)
3384: import polars as pl
3385: import pyarrow as pa
3386: from blake3 import blake3
3387: from opentelemetry import metrics, trace
3388: from pydantic import BaseModel, ValidationError
3389:
3390: # Contract infrastructure - ACTUAL INTEGRATION
3391: from farfan_pipeline.core.runtime_config import RuntimeConfig, get_runtime_config
3392: from farfan_pipeline.core.contracts.runtime_contracts import (
3393:     SegmentationMethod,
3394:     SegmentationInfo,
3395:     FallbackCategory,
3396: )
3397: from farfan_pipeline.core.observability.structured_logging import log_fallback
3398: from farfan_pipeline.core.observability.metrics import (
3399:     increment_fallback,
3400:     increment_segmentation_method,
3401: )
3402: from farfan_pipeline.utils.contract_io import ContractEnvelope
3403: from farfan_pipeline.utils.json_logger import get_json_logger, log_io_event
3404: from farfan_pipeline.utils.paths import reports_dir
3405:
3406: from farfan_pipeline.flux.models import (
3407:     AggregateDeliverable,
3408:     AggregateExpectation,
3409:     ChunkDeliverable,
3410:     ChunkExpectation,
3411:     DocManifest,
3412:     IngestDeliverable,
3413:     NormalizeDeliverable,
3414:     NormalizeExpectation,
3415:     PhaseOutcome,
3416:     ReportDeliverable,
```

```
3417:     ReportExpectation,
3418:     ScoreDeliverable,
3419:     ScoreExpectation,
3420:     SignalsDeliverable,
3421:     SignalsExpectation,
3422: )
3423:
3424: if TYPE_CHECKING:
3425:     from collections.abc import Callable
3426:
3427:     from farfan_pipeline.flux.configs import (
3428:         AggregateConfig,
3429:         ChunkConfig,
3430:         NormalizeConfig,
3431:         ReportConfig,
3432:         ScoreConfig,
3433:         SignalsConfig,
3434:     )
3435:
3436: logger = logging.getLogger(__name__)
3437: tracer = trace.get_tracer("flux")
3438: meter = metrics.get_meter("flux")
3439:
3440: # Metrics
3441: phase_counter = meter.create_counter(
3442:     "flux.phase.ok", description="Successful phase executions"
3443: )
3444: phase_error_counter = meter.create_counter(
3445:     "flux.phase.err", description="Failed phase executions"
3446: )
3447: phase_latency_histogram = meter.create_histogram(
3448:     "flux.phase.latency_ms", description="Phase execution latency in milliseconds"
3449: )
3450:
3451:
3452: class PreconditionError(Exception):
3453:     """Raised when a phase precondition is violated."""
3454:
3455:     def __init__(self, phase: str, condition: str, message: str) -> None:
3456:         self.phase = phase
3457:         self.condition = condition
3458:         super().__init__(f"Precondition failed in {phase}: {condition} - {message}")
3459:
3460:
3461: class PostconditionError(Exception):
3462:     """Raised when a phase postcondition is violated."""
3463:
3464:     def __init__(self, phase: str, condition: str, message: str) -> None:
3465:         self.phase = phase
3466:         self.condition = condition
3467:         super().__init__(f"Postcondition failed in {phase}: {condition} - {message}")
3468:
3469:
3470: class CompatibilityError(Exception):
3471:     """Raised when phase compatibility validation fails."""
3472:
```

```
3473:     def __init__(  
3474:         self, source: str, target: str, validation_error: ValidationError  
3475:     ) -> None:  
3476:         self.source = source  
3477:         self.target = target  
3478:         self.validation_error = validation_error  
3479:         super().__init__(  
3480:             f"Compatibility error {source} \u2026 {target}: {validation_error}"  
3481:         )  
3482:  
3483:  
3484: def _fp(d: BaseModel | dict[str, Any]) -> str:  
3485:     """  
3486:     Compute deterministic fingerprint.  
3487:  
3488:     requires: d is not None  
3489:     ensures: result is 64-char hex string  
3490:     """  
3491:     if d is None:  
3492:         raise PreconditionError("_fp", "d is not None", "Input cannot be None")  
3493:  
3494:     b = (  
3495:         d.model_dump_json() if isinstance(d, BaseModel) else json.dumps(d, sort_keys=True)  
3496:     ).encode()  
3497:     result = blake3(b"FLUX-2025.1" + b).hexdigest()  
3498:  
3499:     if len(result) != 64:  
3500:         raise PostconditionError(  
3501:             "_fp", "result is 64-char hex", f"Got {len(result)} chars"  
3502:         )  
3503:  
3504:     return result  
3505:  
3506:  
3507: def assert_compat(deliverable: BaseModel, expectation_cls: type[BaseModel]) -> None:  
3508:     """  
3509:     Validate compatibility between deliverable and expectation.  
3510:  
3511:     requires: deliverable and expectation_cls are not None  
3512:     ensures: validation passes or CompatibilityError is raised  
3513:     """  
3514:     if deliverable is None or expectation_cls is None:  
3515:         raise PreconditionError(  
3516:             "assert_compat",  
3517:             "inputs not None",  
3518:             "deliverable and expectation_cls must be provided",  
3519:         )  
3520:  
3521:     try:  
3522:         expectation_cls.model_validate(deliverable.model_dump())  
3523:     except ValidationError as ve:  
3524:         raise CompatibilityError(  
3525:             deliverable.__class__.__name__, expectation_cls.__name__, ve  
3526:         ) from ve  
3527:  
3528:
```

```
3529: # NOTE: INGEST phase removed - use SPC (Smart Policy Chunks) via CPPIngestionPipeline
3530: # SPC is the ONLY canonical Phase-One entry point (src/farfan_core/processing/spc_ingestion)
3531: # FLUX phases begin from NORMALIZE, which receives SPC output
3532:
3533:
3534: # NORMALIZE
3535: def run_normalize(
3536:     cfg: NormalizeConfig,
3537:     ing: IngestDeliverable,
3538:     *,
3539:     policy_unit_id: str | None = None,
3540:     correlation_id: str | None = None,
3541:     envelope_metadata: dict[str, str] | None = None,
3542: ) -> PhaseOutcome:
3543:     """
3544:         Execute normalize phase with mandatory metadata propagation.
3545:
3546:         requires: compatible input from ingest
3547:         ensures: sentences list is not empty, sentence_meta matches length, metadata propagated
3548:         """
3549:     start_time = time.time()
3550:     start_monotonic = time.monotonic()
3551:
3552:     # Derive policy_unit_id from environment or generate default
3553:     if policy_unit_id is None:
3554:         policy_unit_id = os.getenv("POLICY_UNIT_ID", "default-policy")
3555:     if correlation_id is None:
3556:         import uuid
3557:         correlation_id = str(uuid.uuid4())
3558:
3559:     # Get contract-aware JSON logger
3560:     contract_logger = get_json_logger("flux.normalize")
3561:
3562:     with tracer.start_as_current_span("normalize") as span:
3563:         # Wrap input with ContractEnvelope for traceability
3564:         env_in = ContractEnvelope.wrap(
3565:             ing.model_dump(),
3566:             policy_unit_id=policy_unit_id,
3567:             correlation_id=correlation_id
3568:         )
3569:
3570:         # Compatibility check
3571:         assert_compat(ing, NormalizeExpectation)
3572:
3573:         if policy_unit_id:
3574:             span.set_attribute("policy_unit_id", policy_unit_id)
3575:         if correlation_id:
3576:             span.set_attribute("correlation_id", correlation_id)
3577:
3578:         # PHASE 2: TEXT NORMALIZATION - MAXIMUM STANDARD IMPLEMENTATION
3579:         # =====
3580:
3581:         logger.info(
3582:             f"Normalizing text with unicode_form={cfg.unicode_form}, "
3583:             f"keep_diacritics={cfg.keep_diacritics}"
3584:         )
```

```
3585:  
3586:     # Step 1: Unicode Normalization (NFC or NFKC)  
3587:     normalized_text = unicodedata.normalize(cfg.unicode_form, ing.raw_text)  
3588:     span.set_attribute("unicode_form", cfg.unicode_form)  
3589:  
3590:     # Step 2: Whitespace Normalization (deterministic)  
3591:     # Replace multiple spaces with single space  
3592:     normalized_text = re.sub(r'[ \t]+', ' ', normalized_text)  
3593:     # Replace multiple newlines with single newline  
3594:     normalized_text = re.sub(r'\n{3,}', '\n\n', normalized_text)  
3595:     # Clean spaces around newlines (but preserve paragraph breaks)  
3596:     normalized_text = re.sub(r' *\n *', '\n', normalized_text)  
3597:     # Remove trailing/leading whitespace  
3598:     normalized_text = normalized_text.strip()  
3599:  
3600:     # Step 3: Diacritic Handling (if configured)  
3601:     if not cfg.keep_diacritics:  
3602:         logger.info("Removing diacritics per configuration")  
3603:         # Decompose to NFD (separates base chars from diacritics)  
3604:         nfd_text = unicodedata.normalize('NFD', normalized_text)  
3605:         # Filter out combining marks (category Mn)  
3606:         no_diacritic_text = ''.join(  
3607:             c for c in nfd_text  
3608:             if unicodedata.category(c) != 'Mn'  
3609:         )  
3610:         # Recompose to NFC  
3611:         normalized_text = unicodedata.normalize('NFC', no_diacritic_text)  
3612:         span.set_attribute("diacritics_removed", True)  
3613:  
3614:     # Step 4: Sentence Segmentation with spaCy (MAXIMUM STANDARD)  
3615:     # Try spaCy with structured downgrade path: LG → MD → SM → REGEX → LINE  
3616:     sentences: list[str] = []  
3617:     sentence_meta: list[dict[str, Any]] = []  
3618:     segmentation_info: SegmentationInfo | None = None  
3619:  
3620:     # Get runtime config for preferred model  
3621:     runtime_config = get_runtime_config()  
3622:     preferred_model = runtime_config.preferred_spacy_model  
3623:  
3624:     # Define downgrade chain based on preferred model  
3625:     model_chain = []  
3626:     if preferred_model == "es_core_news_lg":  
3627:         model_chain = ["es_core_news_lg", "es_core_news_md", "es_core_news_sm"]  
3628:     elif preferred_model == "es_core_news_md":  
3629:         model_chain = ["es_core_news_md", "es_core_news_sm"]  
3630:     elif preferred_model == "es_core_news_sm":  
3631:         model_chain = ["es_core_news_sm"]  
3632:     else:  
3633:         # Unknown model, try default chain  
3634:         model_chain = ["es_core_news_lg", "es_core_news_md", "es_core_news_sm"]  
3635:  
3636:     spacy_success = False  
3637:     actual_model = None  
3638:     downgraded_from = None  
3639:  
3640:     try:
```

```
3641: import spacy
3642:
3643: # Try each model in the chain
3644: for i, model_name in enumerate(model_chain):
3645:     try:
3646:         nlp = spacy.load(model_name)
3647:         actual_model = model_name
3648:
3649:         # Track if we downgraded
3650:         if i > 0:
3651:             downgraded_from = model_chain[0] # Original preferred model
3652:
3653:             # Determine segmentation method
3654:             if model_name == "es_core_news_lg":
3655:                 method = SegmentationMethod.SPACY_LG
3656:             elif model_name == "es_core_news_md":
3657:                 method = SegmentationMethod.SPACY_MD
3658:             else:
3659:                 method = SegmentationMethod.SPACY_SM
3660:
3661:             # Log downgrade
3662:             reason = f"Model {downgraded_from} not available, downgraded to {model_name}"
3663:             logger.warning(reason)
3664:
3665:             segmentation_info = SegmentationInfo(
3666:                 method=method,
3667:                 downgraded_from=SegmentationMethod.SPACY_LG if downgraded_from == "es_core_news_lg" else SegmentationMethod.SPACY_MD,
3668:                 reason=reason
3669:             )
3670:
3671:             # Emit structured log and metrics (Category B: Quality degradation)
3672:             log_fallback(
3673:                 component='text_segmentation',
3674:                 subsystem='flux_normalize',
3675:                 fallback_category=FallbackCategory.B,
3676:                 fallback_mode=f'spacy_downgrade_{model_name}',
3677:                 reason=reason,
3678:                 runtime_mode=runtime_config.mode,
3679:             )
3680:
3681:             increment_fallback(
3682:                 component='text_segmentation',
3683:                 fallback_category=FallbackCategory.B,
3684:                 fallback_mode=f'spacy_downgrade_{model_name}',
3685:                 runtime_mode=runtime_config.mode,
3686:             )
3687:         else:
3688:             # No downgrade, using preferred model
3689:             if model_name == "es_core_news_lg":
3690:                 method = SegmentationMethod.SPACY_LG
3691:             elif model_name == "es_core_news_md":
3692:                 method = SegmentationMethod.SPACY_MD
3693:             else:
3694:                 method = SegmentationMethod.SPACY_SM
3695:
3696:             segmentation_info = SegmentationInfo(
```

```
3697:                     method=method,
3698:                     downgraded_from=None,
3699:                     reason=None
3700:                 )
3701:
3702:             # Emit segmentation method metric
3703:             increment_segmentation_method(
3704:                 method=method,
3705:                 runtime_mode=runtime_config.mode,
3706:             )
3707:
3708:             break # Successfully loaded model
3709:
3710:     except OSError:
3711:         if i == len(model_chain) - 1:
3712:             # Last model in chain also failed, will fall back to regex
3713:             raise
3714:         # Try next model in chain
3715:         continue
3716:
3717:     # Process with spaCy pipeline
3718:     doc = nlp(normalized_text)
3719:
3720:     for i, sent in enumerate(doc.sents):
3721:         sentence_text = sent.text.strip()
3722:         if not sentence_text:
3723:             continue
3724:
3725:         sentences.append(sentence_text)
3726:
3727:         # Rich metadata per sentence
3728:         sentence_meta.append({
3729:             "index": i,
3730:             "length": len(sentence_text),
3731:             "char_start": sent.start_char,
3732:             "char_end": sent.end_char,
3733:             "token_count": len(sent),
3734:             "has_verb": any(token.pos_ == "VERB" for token in sent),
3735:             "num_entities": len(sent.ents),
3736:             "entity_labels": [ent.label_ for ent in sent.ents] if sent.ents else [],
3737:             "root_lemma": sent.root.lemma_ if sent.root else None,
3738:             "root_pos": sent.root.pos_ if sent.root else None,
3739:         })
3740:
3741:     logger.info(f"spaCy segmentation ({actual_model}): {len(sentences)} sentences extracted")
3742:     span.set_attribute("segmentation_method", actual_model)
3743:     spacy_success = True
3744:
3745: except (ImportError, OSError) as e:
3746:     # spaCy not available or all models failed - fall back to regex
3747:     reason = f"spaCy not available or all models failed: {str(e)}"
3748:     logger.warning(f"{reason}, using regex fallback for sentence segmentation")
3749:
3750:     segmentation_info = SegmentationInfo(
3751:         method=SegmentationMethod.REGEX,
3752:         downgraded_from=SegmentationMethod.SPACY_LG if preferred_model == "es_core_news_lg" else None,
```

```
3753:         reason=reason
3754:     )
3755:
3756:     # Emit structured log and metrics (Category B: Quality degradation)
3757:     logFallback(
3758:         component='text_segmentation',
3759:         subsystem='flux_normalize',
3760:         fallback_category=FallbackCategory.B,
3761:         fallback_mode='regex_fallback',
3762:         reason=reason,
3763:         runtime_mode=runtime_config.mode,
3764:     )
3765:
3766:     incrementFallback(
3767:         component='text_segmentation',
3768:         fallback_category=FallbackCategory.B,
3769:         fallback_mode='regex_fallback',
3770:         runtime_mode=runtime_config.mode,
3771:     )
3772:
3773:     incrementSegmentationMethod(
3774:         method=SegmentationMethod.REGEX,
3775:         runtime_mode=runtime_config.mode,
3776:     )
3777:
3778:     span.set_attribute("segmentation_method", "regex_fallback")
3779:
3780:     # FALBACK: Advanced regex-based segmentation
3781:     # Pattern that respects abbreviations, decimals, ellipsis
3782:     # Matches sentence-ending punctuation followed by whitespace and capital letter
3783:     sentence_pattern = r'(?<=[!.?])\s+(?=([A-ZÀ\201À\211À\215À\223À\232À\221]))'
3784:
3785:     # Split by pattern
3786:     raw_sentences = re.split(sentence_pattern, normalized_text)
3787:
3788:     char_pos = 0
3789:     for i, sent_text in enumerate(raw_sentences):
3790:         sent_text = sent_text.strip()
3791:         if not sent_text:
3792:             continue
3793:
3794:         sentences.append(sent_text)
3795:
3796:         sentence_meta.append({
3797:             "index": i,
3798:             "length": len(sent_text),
3799:             "char_start": char_pos,
3800:             "char_end": char_pos + len(sent_text),
3801:             "token_count": len(sent_text.split()),
3802:             "has_verb": None, # Not available without spaCy
3803:             "num_entities": None,
3804:             "entity_labels": [],
3805:             "root_lemma": None,
3806:             "root_pos": None,
3807:         })
3808:
```

```
3809:         char_pos += len(sent_text) + 1 # +1 for space/newline
3810:
3811:     logger.info(f"Regex segmentation: {len(sentences)} sentences extracted")
3812:
3813:     # Final validation - LINE fallback if still no sentences
3814:     if not sentences:
3815:         logger.error("Normalization produced zero sentences - attempting line-based fallback")
3816:
3817:     # Update segmentation info for LINE fallback
3818:     reason = "Both spaCy and regex segmentation produced zero sentences"
3819:     segmentation_info = SegmentationInfo(
3820:         method=SegmentationMethod.LINE,
3821:         downgraded_from=SegmentationMethod.SPACY_LG if preferred_model == "es_core_news_lg" else SegmentationMethod.REGEX,
3822:         reason=reason
3823:     )
3824:
3825:     # Emit structured log and metrics (Category B: Quality degradation)
3826:     logFallback(
3827:         component='text_segmentation',
3828:         subsystem='flux_normalize',
3829:         fallback_category=FallbackCategory.B,
3830:         fallback_mode='line_fallback',
3831:         reason=reason,
3832:         runtime_mode=runtime_config.mode,
3833:     )
3834:
3835:     incrementFallback(
3836:         component='text_segmentation',
3837:         fallback_category=FallbackCategory.B,
3838:         fallback_mode='line_fallback',
3839:         runtime_mode=runtime_config.mode,
3840:     )
3841:
3842:     incrementSegmentationMethod(
3843:         method=SegmentationMethod.LINE,
3844:         runtime_mode=runtime_config.mode,
3845:     )
3846:
3847:     # Last resort: split by newlines (but still normalize each)
3848:     for i, line in enumerate(normalized_text.split('\n')):
3849:         line = line.strip()
3850:
3851:         if line:
3852:             sentences.append(line)
3853:             sentence_meta.append({
3854:                 "index": i,
3855:                 "length": len(line),
3856:                 "char_start": 0,
3857:                 "char_end": len(line),
3858:                 "token_count": len(line.split()),
3859:                 "has_verb": None,
3860:                 "num_entities": None,
3861:                 "entity_labels": [],
3862:                 "root_lemma": None,
3863:                 "root_pos": None,
3864:             })
3865:
```

```
3865:     # Add segmentation info to sentence metadata for observability
3866:     if segmentation_info:
3867:         for meta in sentence_meta:
3868:             meta['segmentation_method'] = segmentation_info.method.value
3869:             if segmentation_info.downgraded_from:
3870:                 meta['downgraded_from'] = segmentation_info.downgraded_from.value
3871:
3872:     out = NormalizeDeliverable(sentences=sentences, sentence_meta=sentence_meta)
3873:
3874:     # Postconditions
3875:     if not out.sentences:
3876:         raise PostconditionError(
3877:             "run_normalize", "non-empty sentences", "Must produce at least one sentence"
3878:         )
3879:
3880:     if len(out.sentences) != len(out.sentence_meta):
3881:         raise PostconditionError(
3882:             "run_normalize",
3883:             "meta length match",
3884:             f"sentences={len(out.sentences)}, meta={len(out.sentence_meta)}",
3885:         )
3886:
3887:     # Wrap output with ContractEnvelope
3888:     env_out = ContractEnvelope.wrap(
3889:         out.model_dump(),
3890:         policy_unit_id=policy_unit_id,
3891:         correlation_id=correlation_id
3892:     )
3893:
3894:     fp = _fp(out)
3895:     span.set_attribute("fingerprint", fp)
3896:     span.set_attribute("sentence_count", len(out.sentences))
3897:     span.set_attribute("correlation_id", correlation_id)
3898:     span.set_attribute("content_digest", env_out.content_digest)
3899:
3900:     duration_ms = (time.time() - start_time) * 1000
3901:     phase_latency_histogram.record(duration_ms, {"phase": "normalize"})
3902:     phase_counter.add(1, {"phase": "normalize"})
3903:
3904:     # Structured JSON logging with envelope metadata
3905:     log_io_event(
3906:         contract_logger,
3907:         phase="normalize",
3908:         envelope_in=env_in,
3909:         envelope_out=env_out,
3910:         started_monotonic=start_monotonic
3911:     )
3912:
3913:     logger.info(
3914:         "phase_complete: phase=%s ok=%s fingerprint=%s duration_ms=%.2f sentence_count=%d",
3915:         "normalize",
3916:         True,
3917:         fp,
3918:         duration_ms,
3919:         len(out.sentences),
3920:     )
```

```
3921:         return PhaseOutcome(
3922:             ok=True,
3923:             phase="normalize",
3924:             payload=out.model_dump(),
3925:             fingerprint=fp,
3926:             policy_unit_id=policy_unit_id,
3927:             correlation_id=correlation_id,
3928:             envelope_metadata={
3929:                 "event_id": env_out.event_id,
3930:                 "content_digest": env_out.content_digest,
3931:                 "schema_version": env_out.schema_version,
3932:             },
3933:             ),
3934:             metrics={"duration_ms": duration_ms, "sentence_count": len(out.sentences)},
3935:         )
3936:
3937:
3938: # CHUNK
3939: def run_chunk(
3940:     cfg: ChunkConfig,
3941:     norm: NormalizeDeliverable,
3942:     *,
3943:     policy_unit_id: str | None = None,
3944:     correlation_id: str | None = None,
3945:     envelope_metadata: dict[str, str] | None = None,
3946: ) -> PhaseOutcome:
3947: """
3948: Execute chunk phase with mandatory metadata propagation.
3949:
3950: requires: compatible input from normalize
3951: ensures: chunks not empty, chunk_index has valid resolutions, metadata propagated
3952: """
3953: start_time = time.time()
3954: start_monotonic = time.monotonic()
3955:
3956: # Derive policy_unit_id from environment or generate default
3957: if policy_unit_id is None:
3958:     policy_unit_id = os.getenv("POLICY_UNIT_ID", "default-policy")
3959: if correlation_id is None:
3960:     import uuid
3961:     correlation_id = str(uuid.uuid4())
3962:
3963: # Get contract-aware JSON logger
3964: contract_logger = get_json_logger("flux.chunk")
3965:
3966: with tracer.start_as_current_span("chunk") as span:
3967:     # Wrap input with ContractEnvelope
3968:     env_in = ContractEnvelope.wrap(
3969:         norm.model_dump(),
3970:         policy_unit_id=policy_unit_id,
3971:         correlation_id=correlation_id
3972:     )
3973:
3974:     # Compatibility check
3975:     assert_compat(norm, ChunkExpectation)
3976:
```

```
3977:         if policy_unit_id:
3978:             span.set_attribute("policy_unit_id", policy_unit_id)
3979:         if correlation_id:
3980:             span.set_attribute("correlation_id", correlation_id)
3981:
3982:         # TODO: Implement actual chunking with token limits and overlap
3983:         chunks: list[dict[str, Any]] = [
3984:             {
3985:                 "id": f"c{i}",
3986:                 "text": s,
3987:                 "resolution": cfg.priority_resolution,
3988:                 "span": {"start": i, "end": i + 1},
3989:             }
3990:             for i, s in enumerate(norm.sentences)
3991:         ]
3992:
3993:         idx: dict[str, list[str]] = {
3994:             "micro": [],
3995:             "meso": [c["id"] for c in chunks if c["resolution"] == "MESO"],
3996:             "macro": [],
3997:         }
3998:
3999:         out = ChunkDeliverable(chunks=chunks, chunk_index=idx)
4000:
4001:     # Postconditions
4002:     if not out.chunks:
4003:         raise PostconditionError(
4004:             "run_chunk", "non-empty chunks", "Must produce at least one chunk"
4005:         )
4006:
4007:     valid_resolutions = {"micro", "meso", "macro"}
4008:     if not all(k in valid_resolutions for k in out.chunk_index):
4009:         raise PostconditionError(
4010:             "run_chunk",
4011:             "valid chunk_index keys",
4012:             f"Keys must be {valid_resolutions}",
4013:         )
4014:
4015:     # Wrap output with ContractEnvelope
4016:     env_out = ContractEnvelope.wrap(
4017:         out.model_dump(),
4018:         policy_unit_id=policy_unit_id,
4019:         correlation_id=correlation_id
4020:     )
4021:
4022:     fp = _fp(out)
4023:     span.set_attribute("fingerprint", fp)
4024:     span.set_attribute("chunk_count", len(out.chunks))
4025:     span.set_attribute("correlation_id", correlation_id)
4026:     span.set_attribute("content_digest", env_out.content_digest)
4027:
4028:     duration_ms = (time.time() - start_time) * 1000
4029:     phase_latency_histogram.record(duration_ms, {"phase": "chunk"})
4030:     phase_counter.add(1, {"phase": "chunk"})
4031:
4032:     # Structured JSON logging with envelope metadata
```

```
4033:         log_io_event(
4034:             contract_logger,
4035:             phase="chunk",
4036:             envelope_in=env_in,
4037:             envelope_out=env_out,
4038:             started_monotonic=start_monotonic
4039:         )
4040:
4041:         logger.info(
4042:             "phase_complete: phase=%s ok=%s fingerprint=%s duration_ms=%.2f chunk_count=%d",
4043:             "chunk",
4044:             True,
4045:             fp,
4046:             duration_ms,
4047:             len(out.chunks),
4048:         )
4049:
4050:         return PhaseOutcome(
4051:             ok=True,
4052:             phase="chunk",
4053:             payload=out.model_dump(),
4054:             fingerprint=fp,
4055:             policy_unit_id=policy_unit_id,
4056:             correlation_id=correlation_id,
4057:             envelope_metadata={
4058:                 "event_id": env_out.event_id,
4059:                 "content_digest": env_out.content_digest,
4060:                 "schema_version": env_out.schema_version,
4061:             },
4062:             metrics={"duration_ms": duration_ms, "chunk_count": len(out.chunks)},
4063:         )
4064:
4065:
4066: # SIGNALS
4067: def run_signals(
4068:     cfg: SignalsConfig,
4069:     ch: ChunkDeliverable,
4070:     *,
4071:     registry_get: Callable[[str], dict[str, Any] | None],
4072:     policy_unit_id: str | None = None,
4073:     correlation_id: str | None = None,
4074:     envelope_metadata: dict[str, str] | None = None,
4075: ) -> PhaseOutcome:
4076:     """
4077:     Execute signals phase (cross-cut) with mandatory metadata propagation.
4078:
4079:     requires: compatible input from chunk, registry_get callable
4080:     ensures: enriched_chunks not empty, used_signals recorded, metadata propagated
4081:     """
4082:     get_json_logger("flux.signals")
4083:     time.monotonic()
4084:     start_time = time.time()
4085:
4086:     with tracer.start_as_current_span("signals") as span:
4087:         # Thread correlation tracking
4088:         if correlation_id:
```

```
4089:     span.set_attribute("correlation_id", correlation_id)
4090:     if policy_unit_id:
4091:         span.set_attribute("policy_unit_id", policy_unit_id)
4092:
4093:         # Compatibility check
4094:         assert_compat(ch, SignalsExpectation)
4095:
4096:         # Wrap input with ContractEnvelope
4097:         env_in = ContractEnvelope.wrap(
4098:             ch.model_dump(),
4099:             policy_unit_id=policy_unit_id or "default",
4100:             correlation_id=correlation_id
4101:         )
4102:         span.set_attribute("input_digest", env_in.content_digest)
4103:
4104:         # Preconditions
4105:         if registry_get is None:
4106:             raise PreconditionError(
4107:                 "run_signals",
4108:                 "registry_get not None",
4109:                 "registry_get must be provided",
4110:             )
4111:
4112:         if policy_unit_id:
4113:             span.set_attribute("policy_unit_id", policy_unit_id)
4114:         if correlation_id:
4115:             span.set_attribute("correlation_id", correlation_id)
4116:
4117:         # Import context filtering utilities
4118:         try:
4119:             from farfan_pipeline.core.orchestrator.signal_context_scoper import (
4120:                 filter_patterns_by_context,
4121:                 create_document_context,
4122:             )
4123:             context_filtering_available = True
4124:         except ImportError:
4125:             context_filtering_available = False
4126:             logger.warning("signal_context_scoper not available, using basic enrichment")
4127:
4128:         enriched = []
4129:         total_patterns_applicable = 0
4130:         chunks_with_signals = 0
4131:
4132:         for chunk in ch.chunks:
4133:             # Extract policy area hint from chunk (if available)
4134:             policy_area_hint = chunk.get("policy_area_hint", "default")
4135:
4136:             # Get signal pack for this chunk's policy area
4137:             pack = registry_get(policy_area_hint)
4138:
4139:             if pack is None:
4140:                 # No signals available for this chunk
4141:                 enriched.append({
4142:                     **chunk,
4143:                     "signal_enriched": False,
4144:                     "applicable_patterns": [],
```

```
4145:                 "pattern_count": 0,
4146:             })
4147:         continue
4148:
4149:     # Extract patterns from pack
4150:     patterns = pack.get("patterns", [])
4151:
4152:     if context_filtering_available and patterns:
4153:         # Create document context from chunk metadata
4154:         doc_context = create_document_context(
4155:             section=chunk.get("section"),
4156:             chapter=chunk.get("chapter"),
4157:             page=chunk.get("page"),
4158:             policy_area=policy_area_hint,
4159:         )
4160:
4161:         # Filter patterns by context (SMART IRRIGATION)
4162:         applicable_patterns, filtering_stats = filter_patterns_by_context(
4163:             patterns, doc_context
4164:         )
4165:
4166:         # Enrich chunk with context-filtered patterns
4167:         enriched.append({
4168:             **chunk,
4169:             "signal_enriched": True,
4170:             "applicable_patterns": [
4171:                 {
4172:                     "pattern_id": p.get("id"),
4173:                     "pattern": p.get("pattern"),
4174:                     "category": p.get("category"),
4175:                     "confidence_weight": p.get("confidence_weight", 0.5),
4176:                 }
4177:                 for p in applicable_patterns[:50] # Limit to avoid bloat
4178:             ],
4179:             "pattern_count": len(applicable_patterns),
4180:             "filtering_stats": filtering_stats,
4181:             "policy_area": policy_area_hint,
4182:         })
4183:
4184:         total_patterns_applicable += len(applicable_patterns)
4185:         chunks_with_signals += 1
4186:
4187:         logger.debug(
4188:             "chunk_signal_enrichment",
4189:             chunk_id=chunk.get("id"),
4190:             policy_area=policy_area_hint,
4191:             total_patterns=filtering_stats["total_patterns"],
4192:             applicable_patterns=len(applicable_patterns),
4193:             context_filtered=filtering_stats["context_filtered"],
4194:             scope_filtered=filtering_stats["scope_filtered"],
4195:         )
4196:     else:
4197:         # Fallback: no context filtering, include all patterns (limited)
4198:         enriched.append({
4199:             **chunk,
4200:             "signal_enriched": True,
```

```

4201:             "applicable_patterns": [
4202:                 {
4203:                     "pattern_id": p.get("id"),
4204:                     "pattern": p.get("pattern"),
4205:                     "category": p.get("category"),
4206:                 }
4207:                 for p in patterns[:50] # Limit to first 50
4208:             ],
4209:             "pattern_count": len(patterns),
4210:             "policy_area": policy_area_hint,
4211:         })
4212:         total_patterns_applicable += len(patterns)
4213:         chunks_with_signals += 1
4214:
4215:     used_signals = {
4216:         "present": chunks_with_signals > 0,
4217:         "chunks_enriched": chunks_with_signals,
4218:         "total_chunks": len(chunks),
4219:         "total_patterns_applicable": total_patterns_applicable,
4220:         "avg_patterns_per_chunk": (
4221:             total_patterns_applicable / chunks_with_signals
4222:             if chunks_with_signals > 0
4223:             else 0
4224:         ),
4225:         "context_filtering_enabled": context_filtering_available,
4226:     }
4227:
4228:     out = SignalsDeliverable(enriched_chunks=enriched, used_signals=used_signals)
4229:
4230:     # Postconditions
4231:     if not out.enriched_chunks:
4232:         raise PostconditionError(
4233:             "run_signals", "non-empty enriched_chunks", "Must have at least one chunk"
4234:         )
4235:
4236:     if "present" not in out.used_signals:
4237:         raise PostconditionError(
4238:             "run_signals",
4239:             "used_signals.present exists",
4240:             "used_signals must indicate presence",
4241:         )
4242:
4243:     fp = _fp(out)
4244:     span.set_attribute("fingerprint", fp)
4245:     span.set_attribute("signals_present", used_signals["present"])
4246:
4247:     # Wrap output with ContractEnvelope
4248:     env_out = ContractEnvelope.wrap(
4249:         out.model_dump(),
4250:         policy_unit_id=policy_unit_id or "default",
4251:         correlation_id=correlation_id
4252:     )
4253:     span.set_attribute("content_digest", env_out.content_digest)
4254:     span.set_attribute("event_id", env_out.event_id)
4255:
4256:     duration_ms = (time.time() - start_time) * 1000

```

```

4257:     phase_latency_histogram.record(duration_ms, {"phase": "signals"})
4258:     phase_counter.add(1, {"phase": "signals"})
4259:
4260:     logger.info(
4261:         "phase_complete: phase=%s ok=%s fingerprint=%s duration_ms=%.2f signals_present=%s "
4262:         "chunks_enriched=%d/%d avg_patterns_per_chunk=% .1f context_filtering=%s policy_unit_id=%s",
4263:         "signals",
4264:         True,
4265:         fp,
4266:         duration_ms,
4267:         used_signals["present"],
4268:         used_signals["chunks_enriched"],
4269:         used_signals["total_chunks"],
4270:         used_signals["avg_patterns_per_chunk"],
4271:         used_signals["context_filtering_enabled"],
4272:         policy_unit_id,
4273:     )
4274:
4275:     return PhaseOutcome(
4276:         ok=True,
4277:         phase="signals",
4278:         payload=out.model_dump(),
4279:         fingerprint=fp,
4280:         policy_unit_id=policy_unit_id,
4281:         correlation_id=correlation_id,
4282:         envelope_metadata={
4283:             "event_id": env_out.event_id,
4284:             "content_digest": env_out.content_digest,
4285:             "schema_version": env_out.schema_version,
4286:         },
4287:         metrics={
4288:             "duration_ms": duration_ms,
4289:             "chunks_enriched": used_signals["chunks_enriched"],
4290:             "total_patterns_applicable": used_signals["total_patterns_applicable"],
4291:             "avg_patterns_per_chunk": used_signals["avg_patterns_per_chunk"],
4292:             "context_filtering_enabled": used_signals["context_filtering_enabled"],
4293:         },
4294:     )
4295:
4296:
4297: # AGGREGATE
4298: def run_aggregate(
4299:     cfg: AggregateConfig,
4300:     sig: SignalsDeliverable,
4301:     *,
4302:     policy_unit_id: str | None = None,
4303:     correlation_id: str | None = None,
4304:     envelope_metadata: dict[str, str] | None = None,
4305: ) -> PhaseOutcome:
4306:     """
4307:     Execute aggregate phase with mandatory metadata propagation.
4308:
4309:     requires: compatible input from signals, group_by not empty
4310:     ensures: features table has required columns, aggregation_meta recorded, metadata propagated
4311:     """
4312:     get_json_logger("flux.aggregate")

```

```
4313:     time.monotonic()
4314:     start_time = time.time()
4315:
4316:     with tracer.start_as_current_span("aggregate") as span:
4317:         # Thread correlation tracking
4318:         if correlation_id:
4319:             span.set_attribute("correlation_id", correlation_id)
4320:         if policy_unit_id:
4321:             span.set_attribute("policy_unit_id", policy_unit_id)
4322:
4323:         # Compatibility check
4324:         assert_compat(sig, AggregateExpectation)
4325:
4326:         # Wrap input with ContractEnvelope
4327:         env_in = ContractEnvelope.wrap(
4328:             sig.model_dump(),
4329:             policy_unit_id=policy_unit_id or "default",
4330:             correlation_id=correlation_id
4331:         )
4332:         span.set_attribute("input_digest", env_in.content_digest)
4333:
4334:         # Preconditions
4335:         if not cfg.group_by:
4336:             raise PreconditionError(
4337:                 "run_aggregate",
4338:                 "group_by not empty",
4339:                 "group_by must contain at least one field",
4340:             )
4341:
4342:         if policy_unit_id:
4343:             span.set_attribute("policy_unit_id", policy_unit_id)
4344:         if correlation_id:
4345:             span.set_attribute("correlation_id", correlation_id)
4346:
4347:         # TODO: Implement actual feature engineering
4348:         item_ids = [c.get("id", f"c{i}") for i, c in enumerate(sig.enriched_chunks)]
4349:         patterns = [c.get("patterns_used", 0) for c in sig.enriched_chunks]
4350:
4351:         tbl = pa.table({"item_id": item_ids, "patterns_used": patterns})
4352:
4353:         aggregation_meta: dict[str, Any] = {
4354:             "rows": tbl.num_rows,
4355:             "group_by": cfg.group_by,
4356:             "feature_set": cfg.feature_set,
4357:         }
4358:
4359:         out = AggregateDeliverable(features=tbl, aggregation_meta=aggregation_meta)
4360:
4361:         # Postconditions
4362:         if out.features.num_rows == 0:
4363:             raise PostconditionError(
4364:                 "run_aggregate", "non-empty features", "Features table must have rows"
4365:             )
4366:
4367:         required_columns = {"item_id"}
4368:         actual_columns = set(out.features.column_names)
```

```
4369:     if not required_columns.issubset(actual_columns):
4370:         missing = required_columns - actual_columns
4371:         raise PostconditionError(
4372:             "run_aggregate",
4373:             "required columns present",
4374:             f"Missing columns: {missing}",
4375:         )
4376:
4377:     fp = _fp(aggregation_meta)
4378:     span.set_attribute("fingerprint", fp)
4379:     span.set_attribute("feature_count", tbl.num_rows)
4380:
4381:     # Wrap output with ContractEnvelope
4382:     payload_dict = {"rows":tbl.num_rows, "meta": aggregation_meta}
4383:     env_out = ContractEnvelope.wrap(
4384:         payload_dict,
4385:         policy_unit_id=policy_unit_id or "default",
4386:         correlation_id=correlation_id
4387:     )
4388:     span.set_attribute("content_digest", env_out.content_digest)
4389:     span.set_attribute("event_id", env_out.event_id)
4390:
4391:     duration_ms = (time.time() - start_time) * 1000
4392:     phase_latency_histogram.record(duration_ms, {"phase": "aggregate"})
4393:     phase_counter.add(1, {"phase": "aggregate"})
4394:
4395:     logger.info(
4396:         "phase_complete: phase=%s ok=%s fingerprint=%s duration_ms=%.2f feature_count=%d",
4397:         "aggregate",
4398:         True,
4399:         fp,
4400:         duration_ms,
4401:         tbl.num_rows,
4402:     )
4403:
4404:     return PhaseOutcome(
4405:         ok=True,
4406:         phase="aggregate",
4407:         payload=payload_dict,
4408:         fingerprint=fp,
4409:         policy_unit_id=policy_unit_id,
4410:         correlation_id=correlation_id,
4411:         envelope_metadata=envelope_metadata or {},
4412:         metrics={"duration_ms": duration_ms, "feature_count":tbl.num_rows},
4413:     )
4414:
4415:
4416: # SCORE
4417: def run_score(
4418:     cfg: ScoreConfig,
4419:     agg: AggregateDeliverable,
4420:     *,
4421:     policy_unit_id: str | None = None,
4422:     correlation_id: str | None = None,
4423:     envelope_metadata: dict[str, str] | None = None,
4424: ) -> PhaseOutcome:
```

```
4425: """
4426: Execute score phase with mandatory metadata propagation.
4427:
4428: requires: compatible input from aggregate, metrics not empty
4429: ensures: scores dataframe not empty, has required columns, metadata propagated
4430: """
4431: get_json_logger("flux.score")
4432: time.monotonic()
4433: start_time = time.time()
4434:
4435: with tracer.start_as_current_span("score") as span:
4436:     # Thread correlation tracking
4437:     if correlation_id:
4438:         span.set_attribute("correlation_id", correlation_id)
4439:     if policy_unit_id:
4440:         span.set_attribute("policy_unit_id", policy_unit_id)
4441:
4442:     # Compatibility check
4443:     assert_compat(agg, ScoreExpectation)
4444:
4445:     # Wrap input with ContractEnvelope
4446:     input_payload = {"rows": agg.features.num_rows, "meta": agg.aggregation_meta}
4447:     env_in = ContractEnvelope.wrap(
4448:         input_payload,
4449:         policy_unit_id=policy_unit_id or "default",
4450:         correlation_id=correlation_id
4451:     )
4452:     span.set_attribute("input_digest", env_in.content_digest)
4453:
4454:     # Preconditions
4455:     if not cfg.metrics:
4456:         raise PreconditionError(
4457:             "run_score", "metrics not empty", "metrics list must not be empty"
4458:         )
4459:
4460:     if policy_unit_id:
4461:         span.set_attribute("policy_unit_id", policy_unit_id)
4462:     if correlation_id:
4463:         span.set_attribute("correlation_id", correlation_id)
4464:
4465:     # TODO: Implement actual scoring logic
4466:     item_ids = agg.features.column("item_id").to_pylist()
4467:
4468:     # Create scores for each metric
4469:     data: dict[str, list[Any]] = {
4470:         "item_id": item_ids * len(cfg.metrics),
4471:         "metric": [m for m in cfg.metrics for _ in item_ids],
4472:         "value": [1.0] * (len(item_ids) * len(cfg.metrics)),
4473:     }
4474:
4475:     df = pl.DataFrame(data)
4476:
4477:     calibration: dict[str, Any] = {"mode": cfg.calibration_mode}
4478:
4479:     out = ScoreDeliverable(scores=df, calibration=calibration)
4480:
```

```
4481:     # Postconditions
4482:     if out.scores.height == 0:
4483:         raise PostconditionError(
4484:             "run_score", "non-empty scores", "Scores dataframe must have rows"
4485:         )
4486:
4487:     required_cols = {"item_id", "metric", "value"}
4488:     actual_cols = set(out.scores.columns)
4489:     if not required_cols.issubset(actual_cols):
4490:         missing = required_cols - actual_cols
4491:         raise PostconditionError(
4492:             "run_score", "required columns present", f"Missing columns: {missing}"
4493:         )
4494:
4495:     fp = _fp({"n": df.height, "calibration": calibration})
4496:     span.set_attribute("fingerprint", fp)
4497:     span.set_attribute("score_count", df.height)
4498:
4499:     # Wrap output with ContractEnvelope
4500:     payload_dict = {"n": df.height}
4501:     env_out = ContractEnvelope.wrap(
4502:         payload_dict,
4503:         policy_unit_id=policy_unit_id or "default",
4504:         correlation_id=correlation_id
4505:     )
4506:     span.set_attribute("content_digest", env_out.content_digest)
4507:     span.set_attribute("event_id", env_out.event_id)
4508:
4509:     duration_ms = (time.time() - start_time) * 1000
4510:     phase_latency_histogram.record(duration_ms, {"phase": "score"})
4511:     phase_counter.add(1, {"phase": "score"})
4512:
4513:     logger.info(
4514:         "phase_complete: phase=%s ok=%s fingerprint=%s duration_ms=%.2f score_count=%d",
4515:         "score",
4516:         True,
4517:         fp,
4518:         duration_ms,
4519:         df.height,
4520:     )
4521:
4522:     return PhaseOutcome(
4523:         ok=True,
4524:         phase="score",
4525:         payload=payload_dict,
4526:         fingerprint=fp,
4527:         policy_unit_id=policy_unit_id,
4528:         correlation_id=correlation_id,
4529:         envelope_metadata=envelope_metadata or {},
4530:         metrics={"duration_ms": duration_ms, "score_count": df.height},
4531:     )
4532:
4533:
4534: # REPORT
4535: def run_report(
4536:     cfg: ReportConfig,
```

```
4537:     sc: ScoreDeliverable,
4538:     manifest: DocManifest,
4539:     *,
4540:     policy_unit_id: str | None = None,
4541:     correlation_id: str | None = None,
4542:     envelope_metadata: dict[str, str] | None = None,
4543: ) -> PhaseOutcome:
4544:     """
4545:     Execute report phase with mandatory metadata propagation.
4546:
4547:     requires: compatible input from score, manifest not None
4548:     ensures: artifacts not empty, summary contains required fields, metadata propagated
4549:     """
4550:     get_json_logger("flux.report")
4551:     time.monotonic()
4552:     start_time = time.time()
4553:
4554:     with tracer.start_as_current_span("report") as span:
4555:         # Thread correlation tracking
4556:         if correlation_id:
4557:             span.set_attribute("correlation_id", correlation_id)
4558:         if policy_unit_id:
4559:             span.set_attribute("policy_unit_id", policy_unit_id)
4560:
4561:         # Compatibility check
4562:         assert_compat(sc, ReportExpectation)
4563:
4564:         # Wrap input with ContractEnvelope
4565:         input_payload = {"n": sc.scores.height}
4566:         env_in = ContractEnvelope.wrap(
4567:             input_payload,
4568:             policy_unit_id=policy_unit_id or "default",
4569:             correlation_id=correlation_id
4570:         )
4571:         span.set_attribute("input_digest", env_in.content_digest)
4572:
4573:         # Preconditions
4574:         if manifest is None:
4575:             raise PreconditionError(
4576:                 "run_report", "manifest not None", "manifest must be provided"
4577:             )
4578:
4579:         if policy_unit_id:
4580:             span.set_attribute("policy_unit_id", policy_unit_id)
4581:         if correlation_id:
4582:             span.set_attribute("correlation_id", correlation_id)
4583:
4584:         # TODO: Implement actual report generation
4585:         artifacts: dict[str, str] = {}
4586:
4587:         # Use reports directory instead of /tmp
4588:         report_base = reports_dir() / "flux_summaries"
4589:         report_base.mkdir(parents=True, exist_ok=True)
4590:
4591:         for fmt in cfg.formats:
4592:             artifact_path = str(report_base / f"{manifest.document_id}.summary.{fmt}")
```

```
4593:         artifacts[f"summary.{fmt}"] = artifact_path
4594:
4595:     summary: dict[str, Any] = {
4596:         "items": sc.scores.height,
4597:         "document_id": manifest.document_id,
4598:         "include_provenance": cfg.include_provenance,
4599:     }
4600:
4601:     out = ReportDeliverable(artifacts=artifacts, summary=summary)
4602:
4603:     # Postconditions
4604:     if not out.artifacts:
4605:         raise PostconditionError(
4606:             "run_report", "non-empty artifacts", "Must produce at least one artifact"
4607:         )
4608:
4609:     if "items" not in out.summary:
4610:         raise PostconditionError(
4611:             "run_report", "summary.items present", "Summary must contain items count"
4612:         )
4613:
4614:     fp = _fp(out)
4615:     span.set_attribute("fingerprint", fp)
4616:     span.set_attribute("artifact_count", len(out.artifacts))
4617:
4618:     # Wrap output with ContractEnvelope (final phase)
4619:     env_out = ContractEnvelope.wrap(
4620:         out.model_dump(),
4621:         policy_unit_id=policy_unit_id or "default",
4622:         correlation_id=correlation_id
4623:     )
4624:     span.set_attribute("content_digest", env_out.content_digest)
4625:     span.set_attribute("event_id", env_out.event_id)
4626:
4627:     duration_ms = (time.time() - start_time) * 1000
4628:     phase_latency_histogram.record(duration_ms, {"phase": "report"})
4629:     phase_counter.add(1, {"phase": "report"})
4630:
4631:     logger.info(
4632:         "phase_complete: phase=%s ok=%s fingerprint=%s duration_ms=%,.2f artifact_count=%d policy_unit_id=%s",
4633:         "report",
4634:         True,
4635:         fp,
4636:         duration_ms,
4637:         len(out.artifacts),
4638:         policy_unit_id,
4639:     )
4640:
4641:     return PhaseOutcome(
4642:         ok=True,
4643:         phase="report",
4644:         payload=out.model_dump(),
4645:         fingerprint=fp,
4646:         policy_unit_id=policy_unit_id,
4647:         correlation_id=correlation_id,
4648:         envelope_metadata={
```

```
4649:             "event_id": env_out.event_id,
4650:             "content_digest": env_out.content_digest,
4651:             "schema_version": env_out.schema_version,
4652:         },
4653:         metrics={"duration_ms": duration_ms, "artifact_count": len(out.artifacts)},
4654:     )
4655:
4656:
4657:
4658: =====
4659: FILE: src/farfan_pipeline/infrastructure/__init__.py
4660: =====
4661:
4662: """Infrastructure package - Adapters for ports.
4663:
4664: This package contains concrete implementations of port interfaces.
4665: Adapters handle external dependencies like file systems, databases, and APIs.
4666:
4667: Structure:
4668: - filesystem.py: File system operations
4669: - environment.py: Environment variable access
4670: - clock.py: Time operations
4671: - log_adapters.py: Logging operations (renamed from logging.py to avoid shadowing)
4672: - recommendation_engine_adapter.py: Recommendation engine adapter
4673: """
4674:
4675: from farfan_pipeline.infrastructure.recommendation_engine_adapter import (
4676:     RecommendationEngineAdapter,
4677:     create_recommendation_engine_adapter,
4678: )
4679:
4680: __all__ = [
4681:     "RecommendationEngineAdapter",
4682:     "create_recommendation_engine_adapter",
4683: ]
4684:
4685:
4686:
4687: =====
4688: FILE: src/farfan_pipeline/infrastructure/clock.py
4689: =====
4690:
4691: """
4692: Clock adapter - Concrete implementation of ClockPort.
4693:
4694: Provides access to current time.
4695: For testing, use FrozenClockAdapter instead.
4696: """
4697:
4698: from datetime import datetime, timezone
4699:
4700:
4701: class SystemClockAdapter:
4702:     """Real clock adapter using datetime.now().
4703:
4704:     Example:
```

```
4705:         >>> clock_port = SystemClockAdapter()
4706:         >>> now = clock_port.now()
4707:         >>> utc_now = clock_port.utcnow()
4708:         """
4709:
4710:     def now(self) -> datetime:
4711:         """Get current datetime."""
4712:         return datetime.now()
4713:
4714:     def utcnow(self) -> datetime:
4715:         """Get current UTC datetime."""
4716:         return datetime.now(timezone.utc)
4717:
4718: class FrozenClockAdapter:
4719:     """Frozen clock adapter for testing.
4720:
4721:     Returns a fixed time that can be updated manually.
4722:
4723:     Example:
4724:         >>> clock_port = FrozenClockAdapter(datetime(2024, 1, 1, 12, 0, 0))
4725:         >>> assert clock_port.now() == datetime(2024, 1, 1, 12, 0, 0)
4726:         >>> clock_port.advance(hours=1)
4727:         >>> assert clock_port.now() == datetime(2024, 1, 1, 13, 0, 0)
4728:         """
4729:
4730:     def __init__(self, frozen_time: datetime | None = None) -> None:
4731:         self._frozen_time = frozen_time or datetime.now()
4732:
4733:     def now(self) -> datetime:
4734:         """Get frozen datetime."""
4735:         return self._frozen_time
4736:
4737:     def utcnow(self) -> datetime:
4738:         """Get frozen UTC datetime."""
4739:         # If frozen_time is naive, assume it's UTC
4740:         if self._frozen_time.tzinfo is None:
4741:             return self._frozen_time.replace(tzinfo=timezone.utc)
4742:         return self._frozen_time.astimezone(timezone.utc)
4743:
4744:     def set_time(self, new_time: datetime) -> None:
4745:         """Set the frozen time (for testing)."""
4746:         self._frozen_time = new_time
4747:
4748:     def advance(self, **kwargs: int) -> None:
4749:         """Advance the frozen time by a timedelta (for testing).
4750:
4751:         Args:
4752:             **kwargs: Arguments to timedelta (days, hours, minutes, seconds, etc.)
4753:         """
4754:         from datetime import timedelta
4755:         self._frozen_time += timedelta(**kwargs)
4756:
4757:     __all__ = [
4758:         'SystemClockAdapter',
4759:         'FrozenClockAdapter',
4760:     ]
```

```
4761:  
4762:  
4763:  
4764: =====  
4765: FILE: src/farfan_pipeline/infrastructure/environment.py  
4766: =====  
4767:  
4768: """  
4769: Environment adapter - Concrete implementation of EnvPort.  
4770:  
4771: Provides access to environment variables with type conversion.  
4772: For testing, use InMemoryEnvAdapter instead.  
4773: """  
4774:  
4775: import os  
4776:  
4777:  
4778: class SystemEnvAdapter:  
4779:     """Real environment adapter using os.environ.  
4780:  
4781:     Example:  
4782:         >>> env_port = SystemEnvAdapter()  
4783:         >>> api_key = env_port.get_required("API_KEY")  
4784:         >>> debug = env_port.get_bool("DEBUG", default=False)  
4785:     """  
4786:  
4787:     def get(self, key: str, default: str | None = None) -> str | None:  
4788:         """Get environment variable."""  
4789:         return os.environ.get(key, default)  
4790:  
4791:     def get_required(self, key: str) -> str:  
4792:         """Get required environment variable."""  
4793:         value = os.environ.get(key)  
4794:         if value is None:  
4795:             raise ValueError(f"Required environment variable not set: {key}")  
4796:         return value  
4797:  
4798:     def get_bool(self, key: str, default: bool = False) -> bool:  
4799:         """Get environment variable as boolean."""  
4800:         value = os.environ.get(key)  
4801:         if value is None:  
4802:             return default  
4803:  
4804:         value_lower = value.lower()  
4805:         if value_lower in ('true', 'yes', '1', 'on'):  
4806:             return True  
4807:         elif value_lower in ('false', 'no', '0', 'off'):  
4808:             return False  
4809:         else:  
4810:             return default  
4811:  
4812: class InMemoryEnvAdapter:  
4813:     """In-memory environment adapter for testing.  
4814:  
4815:     Stores environment variables in a dictionary instead of os.environ.  
4816:
```

```
4817:     Example:
4818:         >>> env_port = InMemoryEnvAdapter()
4819:         >>> env_port.set("DEBUG", "true")
4820:         >>> assert env_port.get_bool("DEBUG") is True
4821:         """
4822:
4823:     def __init__(self, initial_env: dict[str, str] | None = None) -> None:
4824:         self._env = initial_env.copy() if initial_env else {}
4825:
4826:     def get(self, key: str, default: str | None = None) -> str | None:
4827:         """Get environment variable."""
4828:         return self._env.get(key, default)
4829:
4830:     def get_required(self, key: str) -> str:
4831:         """Get required environment variable."""
4832:         value = self._env.get(key)
4833:         if value is None:
4834:             raise ValueError(f"Required environment variable not set: {key}")
4835:         return value
4836:
4837:     def get_bool(self, key: str, default: bool = False) -> bool:
4838:         """Get environment variable as boolean."""
4839:         value = self._env.get(key)
4840:         if value is None:
4841:             return default
4842:
4843:         value_lower = value.lower()
4844:         if value_lower in ('true', 'yes', '1', 'on'):
4845:             return True
4846:         elif value_lower in ('false', 'no', '0', 'off'):
4847:             return False
4848:         else:
4849:             return default
4850:
4851:     def set(self, key: str, value: str) -> None:
4852:         """Set environment variable (for testing)."""
4853:         self._env[key] = value
4854:
4855:     def clear(self) -> None:
4856:         """Clear all environment variables (for testing)."""
4857:         self._env.clear()
4858:
4859:     __all__ = [
4860:         'SystemEnvAdapter',
4861:         'InMemoryEnvAdapter',
4862:     ]
4863:
4864:
4865:
4866: =====
4867: FILE: src/farfan_pipeline/infrastructure/filesystem.py
4868: =====
4869:
4870: """
4871: File system adapter - Concrete implementation of FilePort.
4872:
```

```
4873: Provides real file system access using pathlib.Path.
4874: For testing, use InMemoryFileAdapter instead.
4875: """
4876:
4877: import json
4878: from pathlib import Path
4879: from typing import Any
4880:
4881:
4882: class LocalFileAdapter:
4883:     """Real file system adapter using pathlib.
4884:
4885:     Example:
4886:         >>> file_port = LocalFileAdapter()
4887:         >>> content = file_port.read_text("data/plan.txt")
4888:         >>> file_port.write_text("output/result.txt", content)
4889:     """
4890:
4891:     def read_text(self, path: str, encoding: str = "utf-8") -> str:
4892:         """Read text from a file."""
4893:         return Path(path).read_text(encoding=encoding)
4894:
4895:     def write_text(self, path: str, content: str, encoding: str = "utf-8") -> None:
4896:         """Write text to a file."""
4897:         Path(path).write_text(content, encoding=encoding)
4898:
4899:     def read_bytes(self, path: str) -> bytes:
4900:         """Read bytes from a file."""
4901:         return Path(path).read_bytes()
4902:
4903:     def write_bytes(self, path: str, content: bytes) -> None:
4904:         """Write bytes to a file."""
4905:         Path(path).write_bytes(content)
4906:
4907:     def exists(self, path: str) -> bool:
4908:         """Check if a file or directory exists."""
4909:         return Path(path).exists()
4910:
4911:     def mkdir(self, path: str, parents: bool = False, exist_ok: bool = False) -> None:
4912:         """Create a directory."""
4913:         Path(path).mkdir(parents=parents, exist_ok=exist_ok)
4914:
4915: class JsonAdapter:
4916:     """JSON serialization adapter.
4917:
4918:     Example:
4919:         >>> json_port = JsonAdapter()
4920:         >>> data = json_port.loads('{"key": "value"}')
4921:         >>> text = json_port.dumps(data, indent=2)
4922:     """
4923:
4924:     def loads(self, text: str) -> Any:
4925:         """Parse JSON from string."""
4926:         return json.loads(text)
4927:
4928:     def dumps(self, obj: Any, indent: int | None = None) -> str:
```

```
4929:     """Serialize object to JSON string."""
4930:     if indent is not None:
4931:         return json.dumps(obj, indent=indent, ensure_ascii=False, default=str)
4932:     return json.dumps(obj, ensure_ascii=False, default=str)
4933:
4934: class InMemoryFileAdapter:
4935:     """In-memory file adapter for testing.
4936:
4937:     Stores files in a dictionary instead of disk.
4938:
4939:     Example:
4940:         >>> file_port = InMemoryFileAdapter()
4941:         >>> file_port.write_text("test.txt", "content")
4942:         >>> content = file_port.read_text("test.txt")
4943:         >>> assert content == "content"
4944:     """
4945:
4946:     def __init__(self) -> None:
4947:         self._files: dict[str, bytes] = {}
4948:         self._dirs: set[str] = set()
4949:
4950:     def read_text(self, path: str, encoding: str = "utf-8") -> str:
4951:         """Read text from in-memory storage."""
4952:         if path not in self._files:
4953:             raise FileNotFoundError(f"File not found: {path}")
4954:         return self._files[path].decode(encoding)
4955:
4956:     def write_text(self, path: str, content: str, encoding: str = "utf-8") -> None:
4957:         """Write text to in-memory storage."""
4958:         self._files[path] = content.encode(encoding)
4959:
4960:     def read_bytes(self, path: str) -> bytes:
4961:         """Read bytes from in-memory storage."""
4962:         if path not in self._files:
4963:             raise FileNotFoundError(f"File not found: {path}")
4964:         return self._files[path]
4965:
4966:     def write_bytes(self, path: str, content: bytes) -> None:
4967:         """Write bytes to in-memory storage."""
4968:         self._files[path] = content
4969:
4970:     def exists(self, path: str) -> bool:
4971:         """Check if a file or directory exists in memory."""
4972:         return path in self._files or path in self._dirs
4973:
4974:     def mkdir(self, path: str, parents: bool = False, exist_ok: bool = False) -> None:
4975:         """Create a directory in memory."""
4976:         if path in self._dirs and not exist_ok:
4977:             raise FileExistsError(f"Directory already exists: {path}")
4978:         self._dirs.add(path)
4979:
4980:         if parents:
4981:             # Add all parent directories
4982:             parts = Path(path).parts
4983:             for i in range(1, len(parts) + 1):
4984:                 parent = str(Path(*parts[:i]))
```

```
4985:             self._dirs.add(parent)
4986:
4987:     __all__ = [
4988:         'LocalFileAdapter',
4989:         'JsonAdapter',
4990:         'InMemoryFileAdapter',
4991:     ]
4992:
4993:
4994:
4995: =====
4996: FILE: src/farfan_pipeline/infrastructure/log_adapters.py
4997: =====
4998:
4999: """
5000: Logging adapter - Concrete implementation of LogPort.
5001:
5002: Provides structured logging with different implementations.
5003: For testing, use InMemoryLogAdapter instead.
5004: """
5005:
5006: import logging
5007: from typing import Any
5008:
5009:
5010: class StandardLogAdapter:
5011:     """Standard logging adapter using Python's logging module.
5012:
5013:     Example:
5014:         >>> log_port = StandardLogAdapter("my_module")
5015:         >>> log_port.info("Processing started", document_id="123")
5016:     """
5017:
5018:     def __init__(self, name: str = "farfan_core") -> None:
5019:         self._logger = logging.getLogger(name)
5020:
5021:     def debug(self, message: str, **kwargs: Any) -> None:
5022:         """Log debug message."""
5023:         if kwargs:
5024:             self._logger.debug(f"{message} {kwargs}")
5025:         else:
5026:             self._logger.debug(message)
5027:
5028:     def info(self, message: str, **kwargs: Any) -> None:
5029:         """Log info message."""
5030:         if kwargs:
5031:             self._logger.info(f"{message} {kwargs}")
5032:         else:
5033:             self._logger.info(message)
5034:
5035:     def warning(self, message: str, **kwargs: Any) -> None:
5036:         """Log warning message."""
5037:         if kwargs:
5038:             self._logger.warning(f"{message} {kwargs}")
5039:         else:
5040:             self._logger.warning(message)
```

```
5041:
5042:     def error(self, message: str, **kwargs: Any) -> None:
5043:         """Log error message."""
5044:         if kwargs:
5045:             self._logger.error(f"{message} {kwargs}")
5046:         else:
5047:             self._logger.error(message)
5048:
5049: class InMemoryLogAdapter:
5050:     """In-memory logging adapter for testing.
5051:
5052:     Stores log messages in a list instead of emitting them.
5053:
5054:     Example:
5055:         >>> log_port = InMemoryLogAdapter()
5056:         >>> log_port.info("Test message", key="value")
5057:         >>> assert len(log_port.messages) == 1
5058:         >>> assert log_port.messages[0]["message"] == "Test message"
5059:     """
5060:
5061:     def __init__(self) -> None:
5062:         self.messages: list[dict[str, Any]] = []
5063:
5064:     def debug(self, message: str, **kwargs: Any) -> None:
5065:         """Log debug message."""
5066:         self.messages.append({"level": "debug", "message": message, "data": kwargs})
5067:
5068:     def info(self, message: str, **kwargs: Any) -> None:
5069:         """Log info message."""
5070:         self.messages.append({"level": "info", "message": message, "data": kwargs})
5071:
5072:     def warning(self, message: str, **kwargs: Any) -> None:
5073:         """Log warning message."""
5074:         self.messages.append({"level": "warning", "message": message, "data": kwargs})
5075:
5076:     def error(self, message: str, **kwargs: Any) -> None:
5077:         """Log error message."""
5078:         self.messages.append({"level": "error", "message": message, "data": kwargs})
5079:
5080:     def clear(self) -> None:
5081:         """Clear all log messages (for testing)."""
5082:         self.messages.clear()
5083:
5084:     def get_messages_by_level(self, level: str) -> list[dict[str, Any]]:
5085:         """Get all messages of a specific level (for testing)."""
5086:         return [msg for msg in self.messages if msg["level"] == level]
5087:
5088:     __all__ = [
5089:         'StandardLogAdapter',
5090:         'InMemoryLogAdapter',
5091:     ]
5092:
5093:
5094:
5095: =====
5096: FILE: src/farfan_pipeline/infrastructure/recommendation_engine_adapter.py
```

```
5097: =====
5098:
5099: """
5100: Recommendation engine adapter for infrastructure layer.
5101:
5102: Implements RecommendationEnginePort using the concrete RecommendationEngine
5103: from the analysis module. This adapter follows the Ports and Adapters pattern,
5104: allowing the orchestrator to depend on abstractions rather than concrete implementations.
5105:
5106: Version: 1.0.0
5107: """
5108:
5109: import logging
5110: from pathlib import Path
5111: from typing import Any
5112:
5113: logger = logging.getLogger(__name__)
5114:
5115:
5116: class RecommendationEngineAdapter:
5117:     """Adapter implementing RecommendationEnginePort.
5118:
5119:     This adapter wraps the concrete RecommendationEngine from the analysis module,
5120:     providing a clean boundary between the orchestrator (core) and analysis (domain).
5121:     """
5122:
5123:     def __init__(
5124:         self,
5125:         rules_path: str | Path,
5126:         schema_path: str | Path,
5127:         questionnaire_provider: Any = None,
5128:         orchestrator: Any = None,
5129:     ) -> None:
5130:         """Initialize recommendation engine adapter.
5131:
5132:         Args:
5133:             rules_path: Path to recommendation rules JSON file
5134:             schema_path: Path to JSON schema for validation
5135:             questionnaire_provider: QuestionnaireResourceProvider instance
5136:             orchestrator: Orchestrator instance for accessing thresholds (can be set later)
5137:
5138:         Raises:
5139:             ImportError: If RecommendationEngine cannot be imported
5140:             Exception: If engine initialization fails
5141:         """
5142:         self._rules_path = Path(rules_path)
5143:         self._schema_path = Path(schema_path)
5144:         self._questionnaire_provider = questionnaire_provider
5145:         self._orchestrator = orchestrator
5146:         self._engine: Any = None
5147:
5148:         self._initialize_engine()
5149:
5150:     def set_orchestrator(self, orchestrator: Any) -> None:
5151:         """Set orchestrator reference after construction.
5152:
```

```
5153:     This handles circular dependency between orchestrator and recommendation engine.
5154:
5155:     Args:
5156:         orchestrator: Orchestrator instance
5157:
5158:         self._orchestrator = orchestrator
5159:         if self._engine is not None:
5160:             self._engine.orchestrator = orchestrator
5161:
5162:     def _initialize_engine(self) -> None:
5163:         """Initialize the concrete RecommendationEngine.
5164:
5165:         Raises:
5166:             ImportError: If RecommendationEngine cannot be imported
5167:             Exception: If engine initialization fails
5168:
5169:         try:
5170:             from farfan_pipeline.analysis.recommendation_engine import (
5171:                 RecommendationEngine,
5172:             )
5173:
5174:             self._engine = RecommendationEngine(
5175:                 rules_path=str(self._rules_path),
5176:                 schema_path=str(self._schema_path),
5177:                 questionnaire_provider=self._questionnaire_provider,
5178:                 orchestrator=self._orchestrator,
5179:             )
5180:             logger.info(
5181:                 f"RecommendationEngine initialized via adapter: "
5182:                 f"{len(self._engine.rules_by_level.get('MICRO', []))} MICRO, "
5183:                 f"{len(self._engine.rules_by_level.get('MESO', []))} MESO, "
5184:                 f"{len(self._engine.rules_by_level.get('MACRO', []))} MACRO rules"
5185:             )
5186:         except ImportError as e:
5187:             logger.error(f"Failed to import RecommendationEngine: {e}")
5188:             raise ImportError(
5189:                 "RecommendationEngine not available. "
5190:                 "Ensure farfan_pipeline.analysis.recommendation_engine is installed."
5191:             ) from e
5192:         except Exception as e:
5193:             logger.error(f"Failed to initialize RecommendationEngine: {e}")
5194:             raise
5195:
5196:     def generate_all_recommendations(
5197:         self,
5198:         micro_scores: dict[str, float],
5199:         cluster_data: dict[str, Any],
5200:         macro_data: dict[str, Any],
5201:         context: dict[str, Any] | None = None,
5202:     ) -> dict[str, Any]:
5203:         """Generate recommendations at all three levels.
5204:
5205:             Delegates to the concrete RecommendationEngine implementation.
5206:
5207:         Args:
5208:             micro_scores: Dictionary mapping "PA##-DIM##" to scores
```

```
5209:         cluster_data: Dictionary with cluster metrics
5210:         macro_data: Dictionary with macro-level metrics
5211:         context: Optional context for template rendering
5212:
5213:     Returns:
5214:         Dictionary mapping level to RecommendationSet
5215:
5216:     Raises:
5217:         RuntimeError: If engine is not initialized
5218:     """
5219:     if self._engine is None:
5220:         raise RuntimeError("RecommendationEngine not initialized")
5221:
5222:     return self._engine.generate_all_recommendations(
5223:         micro_scores=micro_scores,
5224:         cluster_data=cluster_data,
5225:         macro_data=macro_data,
5226:         context=context,
5227:     )
5228:
5229:     def generate_micro_recommendations(
5230:         self, scores: dict[str, float], context: dict[str, Any] | None = None
5231:     ) -> Any:
5232:         """Generate MICRO-level recommendations.
5233:
5234:     Args:
5235:         scores: Dictionary mapping "PA##-DIM##" to scores
5236:         context: Optional context for template rendering
5237:
5238:     Returns:
5239:         RecommendationSet with MICRO recommendations
5240:
5241:     Raises:
5242:         RuntimeError: If engine is not initialized
5243:     """
5244:     if self._engine is None:
5245:         raise RuntimeError("RecommendationEngine not initialized")
5246:
5247:     return self._engine.generate_micro_recommendations(
5248:         scores=scores, context=context
5249:     )
5250:
5251:     def generate_meso_recommendations(
5252:         self, cluster_data: dict[str, Any], context: dict[str, Any] | None = None
5253:     ) -> Any:
5254:         """Generate MESO-level recommendations.
5255:
5256:     Args:
5257:         cluster_data: Dictionary with cluster metrics
5258:         context: Optional context for template rendering
5259:
5260:     Returns:
5261:         RecommendationSet with MESO recommendations
5262:
5263:     Raises:
5264:         RuntimeError: If engine is not initialized
```

```
5265:     """
5266:     if self._engine is None:
5267:         raise RuntimeError("RecommendationEngine not initialized")
5268:
5269:     return self._engine.generate_meso_recommendations(
5270:         cluster_data=cluster_data, context=context
5271:     )
5272:
5273:     def generate_macro_recommendations(
5274:         self, macro_data: dict[str, Any], context: dict[str, Any] | None = None
5275:     ) -> Any:
5276:         """Generate MACRO-level recommendations.
5277:
5278:         Args:
5279:             macro_data: Dictionary with macro-level metrics
5280:             context: Optional context for template rendering
5281:
5282:         Returns:
5283:             RecommendationSet with MACRO recommendations
5284:
5285:         Raises:
5286:             RuntimeError: If engine is not initialized
5287:         """
5288:         if self._engine is None:
5289:             raise RuntimeError("RecommendationEngine not initialized")
5290:
5291:         return self._engine.generate_macro_recommendations(
5292:             macro_data=macro_data, context=context
5293:         )
5294:
5295:     def reload_rules(self) -> None:
5296:         """Reload recommendation rules from disk.
5297:
5298:         Raises:
5299:             RuntimeError: If engine is not initialized
5300:         """
5301:         if self._engine is None:
5302:             raise RuntimeError("RecommendationEngine not initialized")
5303:
5304:         self._engine.reload_rules()
5305:         logger.info("Recommendation rules reloaded via adapter")
5306:
5307:
5308:     def create_recommendation_engine_adapter(
5309:         rules_path: str | Path,
5310:         schema_path: str | Path,
5311:         questionnaire_provider: Any = None,
5312:         orchestrator: Any = None,
5313:     ) -> RecommendationEngineAdapter:
5314:         """Factory function to create RecommendationEngineAdapter.
5315:
5316:         This is the primary entry point for creating recommendation engine instances
5317:         in the infrastructure layer. It handles initialization and error handling.
5318:
5319:         Args:
5320:             rules_path: Path to recommendation rules JSON file
```

```
5321:     schema_path: Path to JSON schema for validation
5322:     questionnaire_provider: QuestionnaireResourceProvider instance
5323:     orchestrator: Orchestrator instance for accessing thresholds
5324:
5325:     Returns:
5326:         RecommendationEngineAdapter instance
5327:
5328:     Raises:
5329:         ImportError: If RecommendationEngine cannot be imported
5330:         Exception: If engine initialization fails
5331:
5332:     Example:
5333:         >>> from pathlib import Path
5334:         >>> adapter = create_recommendation_engine_adapter(
5335:             ...     rules_path=Path("config/recommendation_rules_enhanced.json"),
5336:             ...     schema_path=Path("rules/recommendation_rules_enhanced.schema.json"),
5337:             ...     questionnaire_provider=provider,
5338:             ...     orchestrator=orch
5339:             ... )
5340: """
5341:     return RecommendationEngineAdapter(
5342:         rules_path=rules_path,
5343:         schema_path=schema_path,
5344:         questionnaire_provider=questionnaire_provider,
5345:         orchestrator=orchestrator,
5346:     )
5347:
5348:
5349: __all__ = [
5350:     "RecommendationEngineAdapter",
5351:     "create_recommendation_engine_adapter",
5352: ]
5353:
5354:
```