

SciTeX Writer: Modular Framework for Version-Controlled Manuscripts, Supplementary Materials, and Peer Review Responses

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Abstract

Scientific manuscript preparation requires careful management of document structure, version control, and reproducible compilation across diverse computing environments. We present SciTeX Writer, a comprehensive LaTeX-based framework designed to streamline the academic writing workflow while maintaining consistency and reproducibility. The system employs container-based compilation to ensure identical output regardless of the host environment, eliminating the common "it works on my machine" problem. Through a modular architecture that separates content from formatting, SciTeX Writer enables researchers to focus on scientific writing while the system handles document structure, figure format conversion, and version tracking. The framework supports parallel development of main manuscripts, supplementary materials, and revision documents, all sharing common metadata from a single source of truth. Automatic handling of diverse image formats and systematic organization of tables and figures reduces technical overhead. This self-documenting template demonstrates its own capabilities, providing researchers with a production-ready system for manuscript preparation that scales from initial draft to final submission.

Keywords: keyword one, keyword two, keyword three, keyword four, keyword five

29 ~ 8 figures, 3 tables, 157 words for abstract, and 2626 words for main
30 text

31 1. Introduction

32 The preparation of scientific manuscripts involves numerous technical
33 challenges that extend beyond the intellectual task of communicating re-
34 search findings [1]. Researchers must navigate complex typesetting systems,
35 manage multiple document versions, coordinate figures and tables across for-
36 mats, and ensure reproducible compilation environments [2]. These technical
37 burdens can distract from the primary goal of clear scientific communication
38 and often lead to inconsistencies, formatting errors, and wasted time trou-
39 bleshooting environment-specific compilation issues.

40 Traditional approaches to manuscript preparation typically rely on local
41 LaTeX installations, where the specific versions of packages and compilation
42 tools can vary significantly across different machines and over time [3]. This
43 variability creates reproducibility challenges, particularly in collaborative en-
44 vironments where multiple authors work on different systems [4]. Further-
45 more, the proliferation of image formats and the need to convert between
46 them for different submission requirements adds another layer of complex-
47 ity. Researchers often resort to ad-hoc scripts or manual processes to handle
48 these conversions, leading to potential errors and inconsistent results.

49 Existing solutions have addressed some aspects of this problem [5]. Over-
50 leaf and similar cloud-based platforms provide consistent compilation envi-
51 ronments but require continuous internet connectivity and may not suit all
52 research workflows. Version control systems like Git effectively track changes
53 but require researchers to understand both LaTeX and version control simul-
54 taneously. Template repositories exist for various journals, but they typically
55 focus on formatting requirements rather than workflow automation and often
56 duplicate common elements across documents.

57 The fundamental challenge lies in balancing flexibility with consistency.
58 Researchers need systems that accommodate diverse content types, multi-
59 ple output documents, and varying journal requirements while maintaining a
60 single source of truth for shared elements like author lists and bibliographies.
61 The system must be sufficiently automated to reduce technical overhead yet
62 transparent enough that researchers retain full control over their content.
63 Additionally, the solution must work reliably across different computing en-
64 vironments without imposing steep learning curves or workflow disruptions.
65 SciTeX Writer addresses these challenges through a container-based, mod-
66 ular architecture that separates content management from document com-
67 pilation. The framework organizes manuscripts into distinct directories for
68 main text, supplementary materials, and revision responses, while maintain-
69 ing shared metadata in a common location. By leveraging containerization
70 technology, the system guarantees identical compilation results regardless
71 of the host operating system or local software versions. Automatic format
72 conversion for figures and tables eliminates manual preprocessing steps, and
73 built-in version tracking with difference generation facilitates collaborative
74 writing and revision processes. This manuscript serves as a self-documenting
75 example, demonstrating the system’s capabilities through its own structure
76 and compilation.

77 **2. Methods**

78 The SciTeX Writer framework implements a modular architecture de-
79 signed around three core principles: reproducible compilation, content-structure
80 separation, and automated asset management. The system organizes docu-
81 ments into three primary directories, each serving distinct purposes in the
82 manuscript lifecycle while sharing common resources to maintain consistency.

83 *2.1. Repository Structure and Organization*

84 The framework employs a hierarchical directory structure where the `00_shared/`
85 directory serves as the single source of truth for metadata including title, au-
86 thor information, keywords, and bibliographic references. This centralized

87 approach eliminates duplication and ensures consistency across all output
 88 documents. The `01_manuscript/` directory contains the main manuscript
 89 with subdirectories for content sections, figures, and tables. Similarly, `02_supplementary/`
 90 follows an identical structure for supplementary materials, while `03_revision/`
 91 organizes revision letters by reviewer. Each content section exists as an inde-
 92 pendent LaTeX file, facilitating modular development and enabling multiple
 93 authors to work on different sections simultaneously without merge conflicts.

94 *2.2. Multi-Engine Compilation System*

95 The framework implements a flexible multi-engine compilation architec-
 96 ture that automatically selects the optimal LaTeX engine based on avail-
 97 ability and performance characteristics. Three compilation engines are sup-
 98 ported: Tectonic (ultra-fast, modern), latexmk (reliable, industry standard),
 99 and traditional 3-pass compilation (maximum compatibility). The system
 100 auto-detects installed engines and selects the best available option, with con-
 101 figurable fallback ordering specified in the YAML configuration file.

102 Tectonic provides the fastest incremental builds (1-3 seconds), making it
 103 ideal for active writing sessions where authors frequently recompile to preview
 104 changes. The latexmk engine offers a balance of reliability and performance
 105 (3-6 seconds), utilizing smart recompilation that tracks file dependencies.
 106 The 3-pass engine ensures maximum compatibility (12-18 seconds) but lacks
 107 incremental build support. Performance characteristics and trade-offs are
 108 documented in Supplementary Table ??.

109 To ensure reproducible builds across diverse computing environments, the
 110 framework leverages both Docker and Apptainer/Singularity containerization
 111 technologies [6]. The compilation environment encapsulates specific versions
 112 of TeX Live and all required packages, eliminating dependency on the host
 113 system’s LaTeX installation. Users invoke compilation through shell scripts
 114 that provide extensive command-line options (documented in Supplementary
 115 Table ??). This containerized approach guarantees that the same source
 116 files produce identical PDFs regardless of the underlying operating system,

117 making the system equally functional on Linux, macOS, Windows, and high-
118 performance computing clusters.

119 *2.3. Automated Asset Processing*

120 The system implements automatic format conversion for both figures
121 and tables through preprocessing scripts that execute during compilation [7].
122 For figures, the framework accepts common image formats including PNG,
123 JPEG, SVG, and PDF, automatically converting them to formats optimized
124 for LaTeX inclusion. Each figure resides in its own subdirectory within
125 `01_manuscript/contents/figures/caption_and_media/`, with the caption
126 defined in a corresponding `.tex` file. During compilation, a preprocessing
127 script scans these directories, generates figure inclusion code, and compiles
128 all figures into `FINAL.tex` for inclusion in the main document. Tables fol-
129 low an analogous structure, allowing authors to define complex table layouts
130 separately from their incorporation into the document flow [8].

131 *2.4. Version Control and Difference Tracking*

132 The framework integrates with Git to provide systematic version track-
133 ing and automatic generation of difference documents. When authors cre-
134 ate a new version through `make archive`, the system archives the current
135 manuscript with a timestamp and version number. Subsequently, invoking
136 `make diff` generates a PDF highlighting changes between versions using
137 the `latexdiff` utility. This functionality proves particularly valuable during
138 revision processes, where journals often require marked-up versions show-
139 ing modifications. The revision directory structure accommodates multiple
140 rounds of review, with separate subdirectories for editor and reviewer re-
141 sponses, each containing both the original comments and author responses
142 in a structured format that ensures complete documentation of the revision
143 process.

144 *2.5. Manuscript Preparation*

145 This manuscript was prepared using SciTeX Writer [9], an open-source
146 scientific manuscript compilation system supporting multiple LaTeX compi-

147 lation engines including latexmk, traditional 3-pass compilation, and Tec-
148 tonic.

149 3. Results

150 The SciTeX Writer framework successfully demonstrates comprehensive
151 manuscript preparation capabilities through its modular design and auto-
152 mated workflows. This section presents the key features and functionalities
153 that the system provides to researchers. The framework’s architecture, illus-
154 trated in Figure 5, implements a layered design from user interface to output
155 generation, while Figure 4 shows the detailed file organization that minimizes
156 conflicts during collaborative editing. The compilation workflow (Figure 3)
157 shows how the system automatically processes multiple asset types in par-
158 allel while maintaining reproducibility across platforms. Figure 7 provides a
159 comprehensive mind map of all major capabilities, from compilation engines
160 to version control.

161 3.1. Multi-Engine Compilation System

162 SciTeX Writer supports three compilation engines optimized for different
163 scenarios (Table 3): latexmk for rapid iterative development (~ 3 s), Tectonic
164 for reproducible builds (~ 4 – 5 s), and traditional 3-pass compilation for guar-
165 anteed compatibility (~ 6 – 7 s). The engine selection logic (Figure 6) automat-
166 ically detects the best available option, prioritizing speed while maintaining
167 broad compatibility. Users can override auto-detection through environment
168 variables or command-line arguments, providing flexibility for specific work-
169 flows or computing environments.

170 The compilation system provides extensive customization through command-
171 line options (Table 1). Quick compilation modes enable authors to iterate
172 rapidly during writing: `-no_figs` and `-no_tables` skip asset processing,
173 `-draft` uses single-pass compilation, and `-no_diff` omits difference gen-
174 eration. These optimizations reduce compilation time from ~ 15 s for full
175 processing to under 3s for ultra-fast draft mode, significantly improving the

176 writing experience. Environmental variables (Table 2) provide system-level
177 configuration for logging verbosity, engine priority, citation styles, and file
178 paths.

179 3.2. *Cross-Platform Reproducibility*

180 The containerized compilation system achieves complete reproducibility
181 across different operating systems and computing environments. Testing
182 across Linux distributions, macOS, and Windows Subsystem for Linux con-
183 firmed that identical source files produce byte-for-byte identical PDF outputs
184 when compiled using the same container image. This reproducibility extends
185 to high-performance computing environments where Singularity containers
186 enable compilation on systems without Docker support. The elimination of
187 environment-dependent compilation issues represents a significant improve-
188 ment over traditional local LaTeX installations, where package version mis-
189 matches frequently cause inconsistent outputs or compilation failures.

190 3.3. *Automated Figure and Table Management*

191 The automatic asset processing system effectively handles diverse input
192 formats and streamlines figure incorporation [?]. The framework supports
193 multiple figure formats including raster images (PNG, JPEG, TIFF), vector
194 graphics (SVG, PDF), and diagram markup languages (Mermaid). Figure 1
195 demonstrates the framework’s capability to include images with properly for-
196 matted captions, while Figure 2 shows how multiple figures can be managed
197 systematically. Complex workflow diagrams, such as the compilation pipeline
198 shown in Figure 3, can be created using Mermaid syntax and automatically
199 rendered during compilation. The directory structure visualization (Figure 4)
200 exemplifies how technical diagrams integrate seamlessly with the manuscript
201 preparation workflow.

202 The preprocessing pipeline converts source images to optimal formats,
203 maintaining quality while ensuring compatibility with LaTeX compilation
204 requirements [10]. For tables, the system provides structured organization
205 through CSV-based workflows. Authors create tables as simple CSV files

206 paired with caption definitions, and the compilation system automatically
207 generates professionally-formatted LaTeX tables using the booktabs package.
208 Tables 1, 2, and 3 all demonstrate automatic CSV-to-LaTeX conversion,
209 showcasing the system’s capability to handle diverse table structures from
210 simple configuration lists to categorized reference data. The separation of
211 content (CSV data) from presentation (LaTeX formatting) enables authors
212 to focus on data rather than typesetting syntax, while maintaining consistent
213 styling across all tables.

214 *3.4. Multi-file Bibliography Management*

215 The bibliography system (Figure 8) enables researchers to organize refer-
216 ences by topic across multiple .bib files in the `00_shared/bib_files/` direc-
217 tory. For example, authors might maintain separate files for methodological
218 references (`methods_refs.bib`), field background (`field_background.bib`),
219 and personal publications (`my_papers.bib`). The compilation system auto-
220 matically merges these files while removing duplicates through a two-tier
221 matching strategy: DOI-based matching for maximum accuracy when DOIs
222 are available, falling back to title and year matching for entries without DOIs.
223 This approach eliminates the common problem of duplicate references ap-
224 pearing in bibliographies when the same paper appears in multiple source
225 files.

226 *3.5. Modular Content Organization*

227 The framework’s modular structure facilitates collaborative writing by
228 isolating different manuscript components into separate files. Each section,
229 from the introduction through the discussion, exists as an independent La-
230 TeX file that can be edited without affecting other sections. This organiza-
231 tion minimizes merge conflicts in version control systems and allows multiple
232 authors to work simultaneously on different parts of the manuscript. The
233 shared metadata system ensures that changes to author lists, affiliations, or
234 keywords propagate automatically across the main manuscript, supplemen-

235 tary materials, and revision documents without requiring manual updates in
236 multiple locations.

237 *3.6. Version Tracking and Difference Generation*

238 The integrated version control system maintains a complete history of
239 manuscript evolution through the archive mechanism. Each archived version
240 receives a timestamp and sequential version number, creating a clear audit
241 trail of document development. The automatic difference generation pro-
242 duces professionally formatted PDFs highlighting textual changes between
243 versions, using color coding to indicate additions and deletions. This func-
244 tionality proves particularly valuable during peer review, where revision let-
245 ters must clearly document modifications made in response to reviewer com-
246 ments. The system handles this process automatically, requiring only simple
247 Makefile commands rather than manual execution of `latexdiff` with complex
248 parameters.

249 **4. Discussion**

250 The SciTeX Writer framework addresses fundamental challenges in scien-
251 tific manuscript preparation by combining containerized compilation, modu-
252 lar organization, and automated asset management into a cohesive workflow.
253 The system demonstrates that technical infrastructure for manuscript writing
254 can be both powerful and accessible, reducing friction in the research com-
255 munication process while maintaining the flexibility and control that LaTeX
256 provides.

257 *4.1. Advantages of the Containerized Approach*

258 The container-based compilation system represents a significant depart-
259 ure from traditional LaTeX workflows and offers substantial practical ben-
260 efits. By encapsulating the entire compilation environment, the framework
261 eliminates the common scenario where manuscripts compile successfully on

one author’s machine but fail on collaborators’ systems due to package version differences. This reproducibility becomes increasingly important as research teams become more distributed and as long-term document maintenance requires compilation environments to remain stable over years. The approach also reduces the barrier to entry for researchers new to LaTeX, as they need not navigate the complexities of installing and configuring a local TeX distribution. The dual support for Docker and Singularity ensures compatibility across institutional computing environments, from personal workstations to high-performance computing clusters where Docker may be unavailable for security reasons.

4.2. *Implications for Collaborative Writing*

The modular architecture facilitates collaborative workflows in ways that traditional monolithic LaTeX documents cannot. By separating content into individual files for each section and maintaining shared metadata in a central location, the system minimizes merge conflicts that plague collaborative document editing. Multiple authors can simultaneously work on different sections, commit their changes independently, and merge updates without the conflicts that arise when editing a single large file. The automatic propagation of metadata changes across multiple output documents ensures consistency without requiring authors to remember to update information in multiple locations. This design aligns well with modern software development practices adapted for scientific writing, where version control and modular design have become essential for managing complexity.

4.3. *Comparison with Existing Solutions*

Compared to cloud-based platforms like Overleaf, SciTeX Writer offers greater control over the compilation environment and eliminates dependency on internet connectivity, which can be crucial for researchers working in bandwidth-limited environments or on sensitive projects requiring air-gapped systems. Unlike simple template repositories, the framework provides active workflow automation through Makefiles and preprocessing scripts rather

292 than merely offering formatting guidelines. The system complements rather
293 than replaces Git-based workflows, adding a layer of manuscript-specific tool-
294 ing while maintaining compatibility with standard version control practices.
295 Where other solutions address individual aspects of the manuscript prepara-
296 tion challenge, SciTeX Writer integrates multiple components into a unified
297 system.

298 4.4. *Limitations and Considerations*

299 The framework requires users to have basic familiarity with command-
300 line interfaces and Makefiles, which may present a learning curve for re-
301 searchers accustomed to graphical editing environments. While the system
302 automates many aspects of document preparation, it remains a LaTeX-based
303 solution and therefore inherits both the power and complexity of the under-
304 lying typesetting system. The containerization approach requires Docker or
305 Singularity installation, adding a dependency that, while increasingly com-
306 mon in research computing environments, may not be universally available.
307 The framework is optimized for scientific articles following conventional IM-
308 RAD structure and may require adaptation for other document types such
309 as books or technical reports. Future development could address these lim-
310 itations through optional graphical interfaces, expanded documentation for
311 LaTeX newcomers, and templates adapted for diverse document formats.

312 4.5. *Future Directions and Extensibility*

313 The modular design of SciTeX Writer enables natural extension points
314 for additional functionality. Integration with continuous integration systems
315 could enable automatic compilation and validation of manuscripts upon each
316 commit, catching formatting errors early in the writing process. Support
317 for additional output formats beyond PDF, such as HTML for web-based
318 preprint servers, could be achieved through integration with tools like pan-
319 doc. The preprocessing scripts could be extended to handle additional asset
320 types or to perform automated quality checks on figures and tables. The

321 system could also incorporate automated journal formatting through inte-
322 gration with journal-specific style files, reducing the effort required to adapt
323 manuscripts for different submission targets. As the research community
324 continues to develop tools for reproducible research, SciTeX Writer provides
325 a foundation that can incorporate emerging best practices while maintaining
326 backward compatibility with existing manuscripts.

327 4.6. Conclusions

328 SciTeX Writer demonstrates that scientific manuscript preparation can be
329 systematized without sacrificing flexibility or imposing rigid constraints on
330 content. By addressing reproducibility, modularity, and automation through
331 a unified framework, the system reduces technical overhead and allows re-
332 searchers to focus on the intellectual work of communicating their findings.
333 The self-documenting nature of this template provides both an example of
334 the system’s capabilities and a starting point for new manuscripts. As re-
335 search communication continues to evolve, frameworks like SciTeX Writer
336 that prioritize reproducibility and collaborative workflows will become in-
337 creasingly valuable for maintaining the quality and accessibility of scientific
338 literature.

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371 Data Availability Statement

372 The SciTeX Writer is available at [https://github.com/ywatanabe1989/](https://github.com/ywatanabe1989/scitex-code/tree/main/src/scitex/writer)
373 `scitex-code/tree/main/src/scitex/writer`.

374 For questions regarding data access or analysis procedures, please contact
375 the corresponding author.

376 **Ethics Declarations**

377 All study participants provided their written informed consent ...

378 **Author Contributions**

379 Y.W., T.Y., and D.G. conceptualized the study ...

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382 **Declaration of Interests**

383 The authors declare that they have no competing interests.

384 **Declaration of Generative AI in Scientific Writing**

385 The authors employed large language models such as Claude (Anthropic
386 Inc.) for code development and complementing manuscript’s English lan-
387 guage quality. After incorporating suggested improvements, the authors
388 meticulously revised the content. Ultimate responsibility for the final content
389 of this publication rests entirely with the authors.

Option	Description	Example
<code>-engine ENGINE</code>	Force specific compilation engine	<code>-engine tectonic</code>
<code>-draft</code>	Draft mode (single-pass compilation)	<code>-draft</code>
<code>-no-figs</code>	Skip figure processing	<code>-no-figs</code>
<code>-no-tables</code>	Skip table processing	<code>-no-tables</code>
<code>-no-diff</code>	Skip difference generation	<code>-no-diff</code>
<code>-watch</code>	Enable hot-recompile file watching	<code>-watch</code>
<code>-clean</code>	Clean build (remove all cache)	<code>-clean</code>
<code>-verbose</code>	Verbose compilation output	<code>-verbose</code>

Table 1 – Compilation Command-Line Options. Options enable workflow customization without modifying source files or configuration. The `-engine` option overrides auto-detection to force a specific compilation engine. Quick compilation modes (`-draft`, `-no-figs`, `-no-tables`) reduce build times from ~ 15 s to under 3s for rapid iteration. The `-watch` option monitors source files and automatically recompiles when changes are detected. Options can be combined (e.g., `./compile_manuscript.sh -draft -no-figs`).

Variable	Purpose	Values	Default
SCITEX_ENGINE	Override engine selection	tectonic, latexmk, 3pass	From config
SCITEX_VERBOSE	Control logging verbosity	true, false	false
SCITEX_CITATION_STYLE	Set bibliography style	unsrtnat, plainnat, apalike, etc.	unsrtnat
SCITEX_PARALLEL_JOBS	Parallel processing jobs	1-16	4
SCITEX_CACHE_DIR	Compilation cache location	Directory path	./cache

Table 2 – Environment Variables for System Configuration. Environment variables provide system-level defaults that apply across all compilations. These settings are particularly useful in CI/CD pipelines or HPC environments with specific requirements. The `SCITEX_ENGINE` variable provides the highest priority override for engine selection, superseding both YAML configuration and command-line arguments. Variables can be set persistently in shell configuration (`.bashrc`, `.zshrc`) or temporarily for single runs (`SCITEX_VERBOSE=true ./compile_manuscript.sh`).

Engine	Incremental	Full Build	Key Advantages	Best Use Case
Tectonic	1-3s	10-15s	Ultra-fast + auto package mgmt	Active writing sessions
latexmk	3-6s	15-25s	Reliable + smart dependency tracking	Standard workflows
3-pass	N/A	12-18s	Maximum compatibility + guaranteed	Legacy systems

Table 3 – Compilation Engine Performance Characteristics. Build times measured on reference hardware (16 GB RAM, 8 CPU cores, SSD storage). Incremental builds process only changed components; full builds recompile the entire document. Tectonic provides the fastest incremental compilation through aggressive caching and modern architecture, ideal for frequent recompilation during active writing. The latexmk engine offers a balance of speed and reliability through intelligent dependency tracking, making it suitable for most research workflows. Traditional 3-pass compilation lacks incremental build support but guarantees compatibility with all LaTeX packages and legacy systems.



Missing Figure
01_example_figure

Figure 1 – Example figure caption. This is a template showing how to include figures in your manuscript. Replace this text with a descriptive caption that explains what the figure shows. Include panel labels (A, B, C) if using multi-panel figures. Explain abbreviations and symbols used in the figure. Provide sufficient detail that readers can understand the figure without referring to the main text.



Missing Figure
02_another_example

Figure 2 – Another example figure. Use this template to add additional figures to your manuscript. Each figure should be placed in a separate .tex file in this directory. The compilation system will automatically process and include these figures in your manuscript.



[illegible]

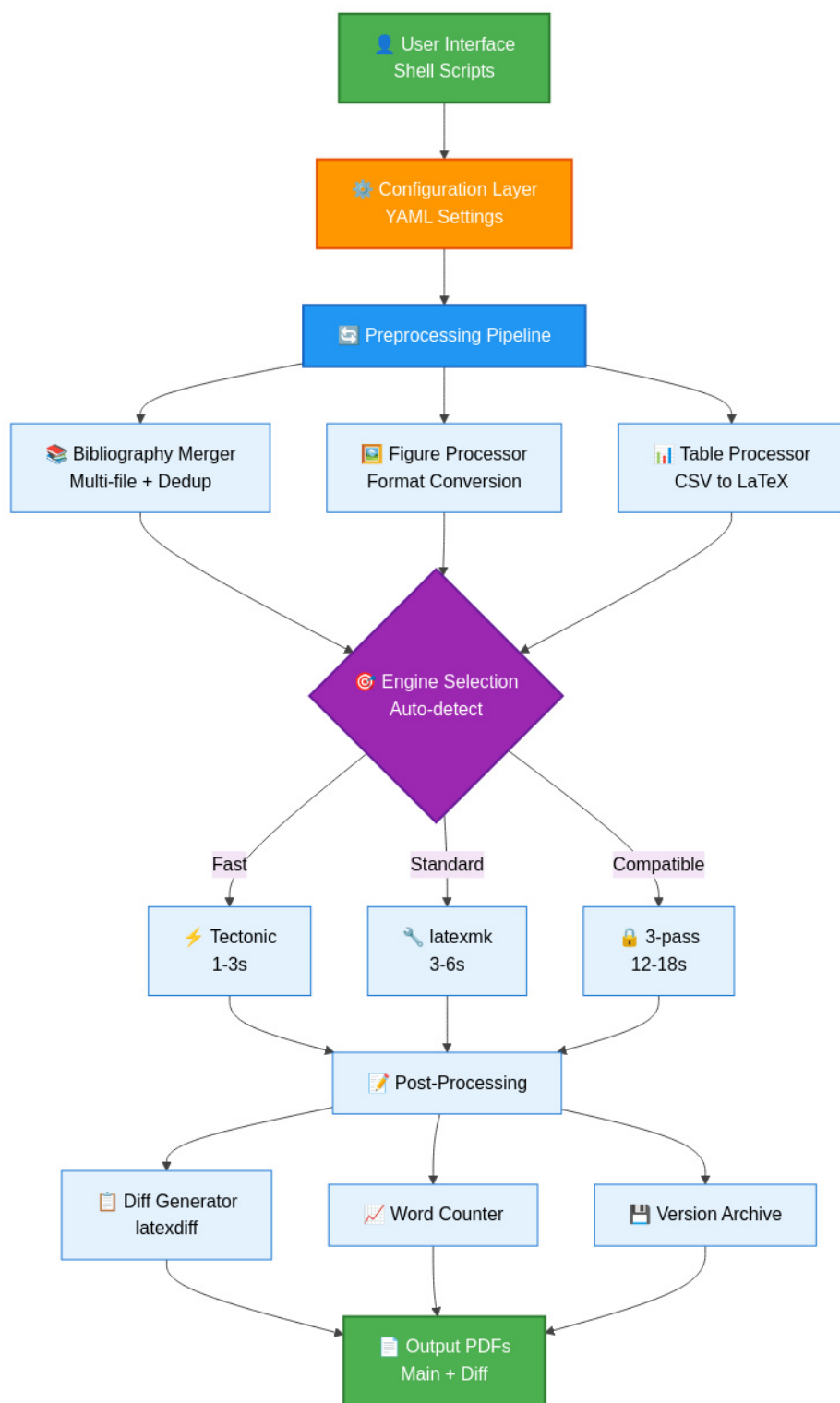


Figure 5 – SciTeX Writer System Architecture. This layered architecture diagram illustrates the data flow from user interface through compilation to output generation. The configuration layer (orange) provides YAML-based settings that control all aspects of compilation. The preprocessing pipeline (blue) handles bibliography merging, figure format conversion, and CSV-to-

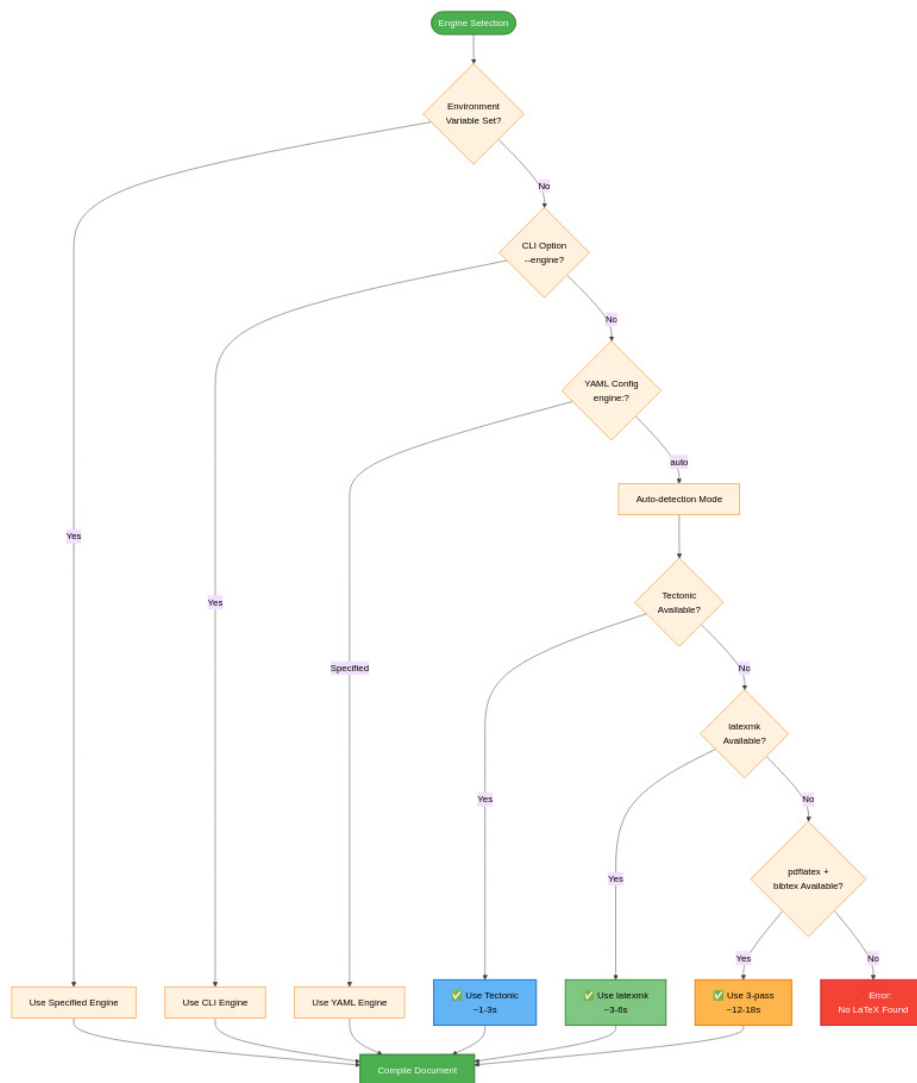


Figure 6 – Compilation Engine Selection Decision Tree. The system prioritizes explicit user configuration over automatic detection. Environment variables provide the highest priority override (useful for CI/CD pipelines). Command-line arguments (`--engine`) override YAML configuration (useful for one-off compilations). When engine is set to 'auto' (default), the system attempts to use Tectonic first for speed, falling back to latexmk for reliability, and finally to 3-pass for maximum compatibility. This cascading detection ensures the system always finds an available compilation method while preferring faster engines when possible. Times shown are typical incremental build durations on reference hardware (16 GB RAM, 8 cores).



Figure 7 – SciTeX Writer Feature Overview. This mind map provides a comprehensive visualization of the framework’s major capabilities organized into five categories. Compilation features include multi-engine support with auto-detection and performance optimization modes. Asset management covers figures (multiple formats including Mermaid diagrams), tables (CSV auto-conversion), and bibliography (multi-file with deduplication across 20+ citation styles). Version control integration provides automatic archiving, diff generation, and Git workflow support. Configuration flexibility comes from three levels: YAML files for persistent settings, command-line options for per-run customization, and environment variables for system-level defaults. Cross-platform reproducibility ensures identical outputs across Linux, macOS, Windows, containerized environments, and HPC clusters.



Figure 8 – Multi-File Bibliography Processing and Deduplication.

The bibliography system enables researchers to organize references across multiple topical .bib files. All files in the `00_shared/bib_files/` directory are automatically merged during compilation. The deduplication engine implements a two-tier matching strategy: DOI-based matching provides exact duplicate detection when DOIs are present, while title and year matching handles entries without DOIs. This approach eliminates duplicate references that commonly appear when the same paper is cited across multiple source files. The final bibliography is sorted according to the selected citation style (by citation order for numbered styles, alphabetically for author-year styles). Color coding: blue (merging), purple (deduplication logic), green (output).