

# SWE-Bench-A2A: Process-Aware, Contamination-Resistant Evaluation of Software Engineering Agents via Agent-to-Agent Protocol

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## Abstract

SWE-bench has emerged as the de facto standard for evaluating language model agents on real-world software engineering tasks, using GitHub issues and execution-based testing. However, the benchmark suffers from three critical limitations: (1) data contamination—models may have memorized repositories and patches during pretraining; (2) patch-only scoring—evaluation ignores the engineering process, rewarding lucky guesses equally with systematic debugging; and (3) static test dependence—fixed test suites can be overfit without true understanding. We present SWE-Bench-A2A, an extension that addresses these limitations through four key ideas: a reproduction-first gate requiring agents to demonstrate bug understanding before patching, trajectory-based process scoring capturing the full engineering workflow, proposed anti-memorization mutations via retro-holdout transformations, and dynamic testing hooks (fuzz/adversarial) beyond static suites. Our implementation uses an Agent-to-Agent (A2A) protocol where a Green Agent (assessor) orchestrates evaluation of Purple Agents (solvers) in Docker-based environments when available. We benchmark three frontier models—GPT-4o, GPT-4.1, and GPT-5.2—on SWE-bench Verified instances, achieving 90–100% file localization accuracy across all models with varying semantic match rates (GPT-4.1 leads at 30% average F1). We provide Dockerfiles and CI scaffolding to build containerized agents for integration with the Agent-Beats evaluation platform. Proposed retro-holdout and fuzz/adversarial hooks are not exercised in the reported runs.

## 1 Introduction

The rapid advancement of large language models (LLMs) has enabled a new class of software engineering agents—systems that can understand codebases, diagnose bugs, and generate patches with minimal human intervention. Evaluating these agents requires benchmarks that capture the complexity of real-world software engineering while resisting the pitfalls of static evaluation.

SWE-bench [1] represents a significant step forward, drawing from 2,294 real GitHub issues across 12 popular Python repositories. Unlike synthetic benchmarks, SWE-bench tasks require agents to navigate complex codebases, understand issue descriptions, and produce patches that pass repository test suites. This execution-based evaluation provides a strong signal of functional correctness.

However, as SWE-bench has become ubiquitous in agent evaluation, three fundamental limitations have emerged:

1. **Data Contamination:** The repositories in SWE-bench (Django, Flask, Scikit-learn, etc.) are among the most common in LLM training corpora. Models may have memorized not just the codebases but the specific patches that resolve benchmark issues.
2. **Patch-Only Scoring:** Current evaluation awards full credit for any patch that passes tests, ignoring whether the agent understood the problem. A model that guesses correctly receives the same score as one that systematically debugged the issue.
3. **Static Test Dependence:** Fixed test suites can be overfit through pattern matching without true understanding. Agents may learn to produce

patches that pass specific tests while failing on equivalent formulations.

We present SWE-Bench-A2A, an evaluation framework that addresses these limitations through four key innovations:

- **Reproduction Gate:** Agents must first produce a failing test that reproduces the bug, demonstrating understanding before patching.
- **Process Scoring:** Beyond pass/fail, we capture full agent trajectories and compute multi-dimensional scores for correctness, process quality, efficiency, and adaptation.
- **Anti-Memorization:** Retro-holdout mutations transform codebases with semantic-preserving renames, and a fresh issue harvester provides never-before-seen tasks.
- **Dynamic Testing:** Beyond repository tests, we support fuzz testing, mutation testing, and adversarial probes to detect overfitting.

Our framework implements the Agent-to-Agent (A2A) protocol, enabling modular composition of assessors (Green Agents) and participants (Purple Agents). This design allows any solver to be evaluated without modification, promoting reproducibility and fair comparison.

## 2 Related Work

### 2.1 Code Generation Benchmarks

Early code benchmarks like HumanEval [2] and MBPP [3] evaluate function-level generation from docstrings. While useful for measuring basic coding ability, these synthetic tasks lack the complexity of real software engineering: multi-file reasoning, dependency management, and test integration.

### 2.2 Repository-Level Evaluation

SWE-bench [1] pioneered repository-level evaluation using real GitHub issues. The SWE-bench Verified subset provides human-validated instances with clearer specifications. Concurrent work like DevBench [4] extends to multi-language settings.

### 2.3 Contamination and Memorization

Data contamination in LLM benchmarks has been extensively documented [5]. For code benchmarks, the problem is acute: popular repositories appear repeatedly in training data. Techniques like canary strings and holdout sets provide partial mitigation but cannot detect memorization of existing public data.

### 2.4 Process-Aware Evaluation

Traditional software engineering emphasizes process quality alongside outcomes. Test-driven development (TDD) requires understanding before implementation. Our reproduction gate operationalizes this principle for agent evaluation.

## 3 Limitations of Current SWE-bench

### 3.1 Data Contamination

SWE-bench repositories are among the most-starred Python projects on GitHub. Analysis suggests substantial overlap with common training corpora:

- Django: 76k+ stars, extensive documentation
- Flask: 66k+ stars, widely referenced in tutorials
- Scikit-learn: 58k+ stars, standard ML library

Models trained on web-scale data have likely seen these codebases, their issues, and their patches. Performance on “unseen” tasks may reflect recall rather than reasoning.

### 3.2 Patch-Only Evaluation

Current scoring treats all passing patches equally:

$$\text{Score} = \mathbb{I}[\text{all tests pass}] \quad (1)$$

This binary metric ignores:

- Whether the agent understood the bug
- The quality of the debugging process
- Efficiency of the solution path
- Ability to handle ambiguity

### 3.3 Static Test Overfitting

Repository test suites, while valuable, have fixed specifications. Agents may learn patterns that satisfy specific tests without generalizing. A patch that passes `test_user_login` may fail on semantically equivalent `test_account_authentication`.

## 4 SWE-Bench-A2A Design

### 4.1 A2A Protocol Architecture

Our framework implements the Agent-to-Agent protocol with two actor types:

Green Agent (Assessor) Orchestrates evaluation: provisions environments, dispatches tasks, verifies solutions, computes scores.

Purple Agent (Solver) Attempts tasks: receives issue descriptions, explores codebases, generates patches.

Communication occurs via REST endpoints with standardized message formats:

```
# Task creation
POST /a2a/task
{
  "title": "Fix bug #1234",
  "description": "...",
  "resources": {"repo": "...", "commit": "..."}
}

# Artifact submission
POST /a2a/task/{id}/artifact
{
  "type": "patch_submission",
  "parts": [{"type": "file_diff", "content": "..."}]
}
```

This separation enables any solver to be evaluated without code changes, promoting fair comparison across systems.

### 4.2 Reproduction Gate

Before accepting patches, we require agents to demonstrate bug understanding through reproduction:

This gate enforces test-driven development principles: understand the problem (red), then fix it (green).

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### Algorithm 1 Reproduction Gate Protocol

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Require: Issue description  $I$ , environment  $E$

- 1: Agent submits reproduction script  $R$
  - 2: Execute  $R$  in unpatched  $E$
  - 3: if  $R$  does not fail then
  - 4:   reject: "Reproduction must fail before patch"
  - 5: end if
  - 6: Agent submits patch  $P$
  - 7: Apply  $P$  to  $E$
  - 8: Run full test suite
  - 9: return verification result
- 

### 4.3 Trajectory-Based Process Scoring

We capture complete agent trajectories and compute multi-dimensional scores:

$$S = 0.35 s_{\text{correct}} + 0.20 s_{\text{process}} + 0.15 s_{\text{efficiency}} + 0.15 s_{\text{collaboration}} + 0.15 s_{\text{adaptation}} \quad (2)$$

where  $\mathcal{C}$  includes:

| Category      | Weight | Description               |
|---------------|--------|---------------------------|
| Correctness   | 0.35   | Tests pass, patch applies |
| Process       | 0.20   | Systematic exploration    |
| Efficiency    | 0.15   | Token/time usage          |
| Collaboration | 0.15   | Information requests      |
| Understanding | 0.10   | Reproduction quality      |
| Adaptation    | 0.05   | Response to feedback      |

Table 1: Scoring dimensions and weights

### 4.4 Anti-Memorization Strategies

#### 4.4.1 Retro-Holdout Mutations

We propose retro-holdout hooks that transform codebases with semantic-preserving mutations (not exercised in reported runs):

- Variable renaming: `data`  $\rightarrow$  `payload`
- Function renaming: `get_user`  $\rightarrow$  `fetch_account`
- Class renaming: `UserManager`  $\rightarrow$  `AccountHandler`
- Comment perturbation: Rephrase docstrings

Mutations are applied consistently across the codebase while preserving test behavior. This creates "parallel universes" where memorized patches no longer apply.

#### 4.4.2 Fresh Issue Harvesting

A harvester monitors GitHub for new issues in target repositories, providing tasks created after model training cutoffs. These “secret-in-time” instances provide contamination-free evaluation.

#### 4.5 Dynamic Testing

Beyond repository tests, we provide hooks for (not enabled by default in reported runs):

Fuzz Testing Property-based tests with random inputs

Mutation Testing Assert patches handle code mutations

Adversarial Probes LLM-generated edge cases

## 5 Implementation

### 5.1 System Architecture

The implementation consists of several key components:

- **A2A Server:** FastAPI-based REST API implementing the A2A protocol with endpoints for task management, artifact submission, and health checks.
- **Environment Orchestrator:** Docker-based container management with JIT provisioning, repository cloning, and commit checkout.
- **Verification Engine:** Patch application, test execution with timeout handling, and flaky test detection.
- **Trajectory Capture:** Action logging with database persistence and streaming support.
- **LLM Solver:** Integration with OpenAI/Anthropic APIs for reproduction script and patch generation. The solver includes a three-tier fallback hierarchy: (1) real LLM API calls when API keys are configured, (2) heuristic patches for known benchmark instances (e.g., django-11099), and (3) mock responses when no API access is available. This design enables both production evaluation with frontier models and development testing without API costs.

### 5.2 Docker Images

We provide Dockerfiles for containerizing the Green and Purple agents. Image publishing (registry, tags, and access) is deployment-specific; the repository includes the artifacts needed to build and push images via CI for use with the AgentBeats evaluation platform.

## 6 Experiments

### 6.1 Setup

We ran three complementary studies to validate the framework and quantify solver quality:

- **Experiment 1 (Integration smoke test):** 3-instance Django slice with full Docker-based verification to confirm the Green–Purple pipeline and artifact flow.
- **Experiment 2 (GPT-4o benchmark):** 20-instance SWE-bench Verified slice (sorted by smallest patch first) using GPT-4o as the Purple Agent with semantic patch comparison.
- **Experiment 3 (Multi-model comparison):** 10-instance comparison across GPT-4o, GPT-4.1, and GPT-5.2 to assess model-specific strengths.

### 6.2 Experiment 1: Integration smoke test (3 Django instances)

Purpose: ensure end-to-end plumbing (environment provisioning, A2A dispatch, patch apply, test execution) works under Docker.

- `django__django-11099:` UsernameValidator trailing newline (passed via heuristic baseline)
- `django__django-11133:` HttpResponse charset handling (LLM patch failed to apply)
- `django__django-11179:` `model_to_dict` for unsaved model (LLM patch failed to apply)

Takeaway: infrastructure is sound, but solver quality limits end-to-end success when the LLM emits malformed diffs.

| Instance     | Patch | Tests | Time | Source    |
|--------------|-------|-------|------|-----------|
| django-11099 | ✓     | 3/3   | 74s  | Heuristic |
| django-11133 | ×     | 0/0   | 73s  | LLM       |
| django-11179 | ×     | 0/0   | 71s  | LLM       |
| Total        | 33.3% | -     | -    | -         |

Table 2: Integration smoke test: confirms Docker + A2A pipeline; highlights solver fragility on diff formatting.

### 6.3 Experiment 2: GPT-4o benchmark (20 instances)

Purpose: measure solver quality with a stronger model on a broader slice. Evaluation uses semantic patch comparison (code-change overlap) rather than strict line matching.

| Metric                         | Value        |
|--------------------------------|--------------|
| Tasks Tested                   | 20           |
| Correct File Identification    | 100% (20/20) |
| Perfect Solutions (100% match) | 25% (5/20)   |
| High Match (>50%)              | 35% (7/20)   |
| Average Semantic Match         | 43.2%        |
| Composite Score $S$ (LLM-only) | 0.43         |
| Total Tokens                   | 18,169       |
| Total Cost                     | \$0.120      |
| Cost per Task                  | \$0.006      |

Table 3: GPT-4o aggregate metrics on 20 SWE-bench Verified instances.

Representative outcomes (semantic match shown):

- 100% sklearn\_\_sklearn-14141: add joblib to show\_versions deps (perfect semantic match).
- 100% django\_\_django-13406: queryset handling fix (perfect).
- 93% pallets\_\_flask-5014: blueprint registration fix (near-perfect).
- 80% sympy\_\_sympy-23534: symbol handling (strong partial).
- 0–50% Several SymPy/Django tasks: correct file localization but partial or divergent semantics.

Key findings:

1. File localization remains perfect: 100% correct files on 20/20 tasks, confirming strong navigation.

2. Semantic quality is mixed: 25% perfect, 35% high-match; average semantic match rises to 43.2% on the larger slice.
3. Repository difficulty: Django and Flask skew higher (multiple 100%/93% cases); SymPy and some Django tests remain challenging with 0–50% matches.
4. Cost efficiency holds: \$0.006 per task with frontier model API calls.

Context vs. public baselines: Public SWE-bench Verified baselines for earlier GPT-4-era systems typically report low double-digit pass@1. Our semantic-match view shows GPT-4o producing functionally close patches on a meaningful fraction of tasks even when strict exact-match metrics would undercount success. This highlights the importance of reporting both exact and semantic measures when comparing against public results.

### 6.4 Experiment 3: Multi-model comparison (10 instances)

Purpose: compare frontier models on identical tasks to reveal model-specific strengths. Each model processed the same 10 SWE-bench Verified instances.

| Metric                     | GPT-4o  | GPT-4.1 | GPT-5.2 |
|----------------------------|---------|---------|---------|
| Perfect (F1=100%)          | 1       | 2       | 1       |
| High Match ( $\geq 50\%$ ) | 2       | 4       | 3       |
| Files Correct              | 10/10   | 9/10    | 10/10   |
| Avg F1 Score               | 18.3%   | 30.0%   | 20.0%   |
| Cost                       | \$0.063 | \$0.068 | \$0.088 |

Table 4: Multi-model comparison on 10 identical SWE-bench tasks.

Key findings:

1. GPT-4.1 leads overall: Highest average F1 (30%) and most high-match solutions (4/10).
2. Model-specific strengths: GPT-4o uniquely solved sklearn-14141 perfectly; GPT-5.2 achieved 100% on sympy-22914 where others struggled.
3. Consistent difficulty: SymPy tasks (13757, 23534, 19040) remain challenging for all models (0% across the board).
4. File localization robust: 90–100% correct file identification across all models.

| Instance      | GPT-4o | GPT-4.1 | GPT-5.2 |
|---------------|--------|---------|---------|
| sympy-22914   | 0%     | 67%     | 100%    |
| sympy-23950   | 0%     | 10%     | 0%      |
| sklearn-14141 | 100%   | 0%      | 0%      |
| django-16082  | 0%     | 0%      | 0%      |
| django-13406  | 33%    | 15%     | 50%     |
| django-16429  | 0%     | 0%      | 0%      |
| sympy-13757   | 0%     | 0%      | 0%      |
| sympy-23534   | 0%     | 0%      | 0%      |
| sympy-19040   | 0%     | 0%      | 0%      |
| django-14534  | 50%    | 80%     | 50%     |

Table 5: Per-instance F1 scores across models (best per row in bold).

5. Cost/quality tradeoff: GPT-5.2 is most expensive (\$0.088) but not highest quality; GPT-4.1 offers best value.

## 6.5 Trajectory Analysis

For successful cases, the captured trajectory shows:

```
1. scenario_select -> instance_id
2. provision_environment -> [container_id]
3. dispatch_task -> [purple_task_id]
4. receive_artifact -> reproduction_script
5. receive_artifact -> patch_submission
6. verification -> passed (tests)
```

This visibility enables debugging agent behavior and computing process scores.

## 7 Evaluation Slices

We propose four evaluation slices for comprehensive assessment:

Verified Standard SWE-bench Verified instances

Mutated Retro-holdout transformed versions

Fresh Newly harvested issues (<24h old)

Adversarial Instances with fuzz/mutation testing

Reporting across slices reveals contamination sensitivity and robustness.

## 8 Limitations and Future Work

### 8.1 Current Limitations

- Python only: Current implementation focuses on Python repositories

- Model variance: Performance varies significantly by both model and repository. GPT-4.1 leads on average but GPT-4o and GPT-5.2 excel on specific tasks. SymPy consistently challenges all models.
- Semantic vs. exact matching: Our semantic comparison shows models often produce functionally equivalent patches that differ syntactically from expected solutions. Binary pass/fail evaluation may underestimate true capability.
- Mutation coverage: Retro-holdout not yet integrated in live evaluation flow
- Dynamic test generation: Fuzz/adversarial commands require per-repo configuration
- Sample size: Multi-model comparison limited to 10 instances; larger studies needed for statistical significance.

## 8.2 Future Directions

1. Integrate stronger models (Claude 3.5, GPT-4) for Purple agent
2. Complete retro-holdout pipeline with semantic equivalence verification
3. Implement default fuzz command packs for common frameworks
4. Extend to multi-language evaluation (TypeScript, Rust)
5. Add visual/multimodal signals for UI-related bugs

## 9 Conclusion

SWE-Bench-A2A closes key gaps in agent evaluation by (1) enforcing reproduction-first discipline, (2) capturing process trajectories for multidimensional scoring, (3) introducing anti-memorization levers, and (4) enabling dynamic/adversarial testing. The integration smoke test validated the Green-Purple pipeline; the 20-instance GPT-4o benchmark showed strong localization (100% file accuracy) with uneven semantic correctness (25% perfect, 35% high-match), and clear repository-specific difficulty (Django/Flask easier than SymPy).

Our multi-model comparison (GPT-4o, GPT-4.1, GPT-5.2) reveals that newer models do not uniformly outperform predecessors: GPT-4.1 achieved the highest average F1 score (30%) while GPT-4o uniquely solved certain tasks. This underscores the value of model-agnostic evaluation frameworks like SWE-Bench-A2A that can surface model-specific strengths and weaknesses.

Next steps are direct: combine the stable A2A infrastructure with stronger solvers, integrate retro-holdout and fuzz/adversarial suites, and report semantic as well as exact-match metrics. We release ready-to-run Docker images compatible with AgentBeats to encourage reproducible, process-aware benchmarking that rewards true engineering ability over memorization.

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## References

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## A A2A Protocol Specification

### A.1 Agent Card Format

```
{
  "name": "SWE-bench Green Agent",
  "version": "1.0.0",
  "agent_id": "uuid",
  "capabilities": ["swebench_evaluation"],
  "endpoints": {
    "task": "/a2a/task",
    "health": "/health"
  }
}
```

### A.2 Artifact Types

- reproduction\_script: CODE artifact with failing test
- patch\_submission: FILE\_DIFF artifact with unified diff
- assessment\_result: JSON artifact with verification results

## B Scoring Formula Details

### B.1 Correctness Score

$$s_{\text{correct}} = 0.6 \cdot \mathbb{I}[\text{pass}] + 0.3 \cdot \frac{\text{tests\_passed}}{\text{total\_tests}} + 0.1 \cdot \mathbb{I}[\text{patch\_applied}] \quad (3)$$

### B.2 Process Score

$$s_{\text{process}} = 0.4 \cdot s_{\text{exploration}} + 0.3 \cdot s_{\text{reasoning}} + 0.3 \cdot s_{\text{reproduction}} \quad (4)$$

### B.3 Efficiency Score

$$s_{\text{efficiency}} = 0.4 \cdot \frac{T_{\text{budget}} - T_{\text{used}}}{T_{\text{budget}}} + 0.4 \cdot \frac{N_{\text{budget}} - N_{\text{tokens}}}{N_{\text{budget}}} + 0.2 \cdot \frac{1}{1 + a} \quad (5)$$