

Architecture Model Extraction Pipeline

architecture-model-standard

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Contents

Architecture Model Extraction Pipeline	3
Overview	3
Complete Data Flow	3
Stage 0: Bootstrap — Config Discovery	3
Entry Point	3
Algorithm	3
Output: ProjectConfig	5
Connections	5
Stage 1: Reality Manifest Generation	5
Entry Point	5
Algorithm	5
Output: Manifest	6
Key Sub-types	6
Performance	6
Connections	6
Stage 2A: Full Extraction (Forward Pass)	6
Entry Point	7
12-Step Pipeline	7
Extended Version: full_extraction_with_docs()	8
Connections	8
Stage 2B: Extract from Code (Backward Pass)	8
Entry Point	8
Algorithm	8
Connections	9
Stage 3: System Boundary Detection	9
Entry Point	9
Algorithm: Multi-Signal Agglomerative Clustering	9
Output: SystemScore	10
Connections	10
Stage 4: Behavior Creation & Trigger Detection	10
Behavior Creation	10
Algorithm	11
Trigger Detection	11
Algorithm	11
Connections	11
Stage 5: Use Case Inference	12
Entry Point	12
Algorithm	12
Example	12
Connections	12
Stage 6: Behavior Decomposition	13
Entry Point	13

Algorithm	13
Output	13
Connections	14
Stage 7: Capability Inference	14
Entry Points	14
Algorithm: Two Strategies	14
Hierarchy Building	14
Connections	14
Stage 8: Behavior Flow Analysis	14
Entry Points	15
Classification Algorithm	15
Flow Tracing	15
Scoped Artifacts	15
Connections	15
Stage 9: Enrichment	15
Entry Points	16
A. File-Based Enrichment (<code>enrich_model</code>)	16
B. Manifest-Based Enrichment (<code>enrich_from_manifest</code>)	16
C. Interface Extraction (<code>extract_component_interfaces</code>)	17
Connections	17
Stage 10: Body Hint Extraction	17
Entry Point	17
Algorithm	17
Trivial Hint Examples	18
Complex Hint Examples	18
Why Body Hints Matter	18
Connections	18
Stage 11: Test Contract Extraction	19
Entry Point	19
Algorithm	19
Output: <code>TestAnalysisResult</code>	19
Contract Types	19
Why Test Contracts Matter	20
Connections	20
Stage 12: Decomposition Pipeline	20
Entry Point	20
Pipeline Steps	20
Output: <code>PipelineResult</code>	21
Connections	21
Stage 13: Model Decomposition (Relationship Tracing)	21
Entry Point	21
Algorithm: Relationship-Driven Splitting	21
Root Model Compaction	22
Connections	23
Stage 14: Deep Decomposition (Import Clustering)	23
Entry Points	23
Algorithm: Import-Graph Clustering	23
Output: <code>DecomposeResult</code>	24
Connections	24
Stage 15: Compaction	24
Entry Point	24
Algorithm	24
Output	25
Storage Pattern	25
Connections	25
Key Data Types Reference	25

Core Model Types	25
Entity Types	26
Enrichment Types	26
Pipeline Types	26
Relationship Types Used in Extraction	26
Token Economics	27
End-to-End Example	27
Appendix: File Reference	28

Architecture Model Extraction Pipeline

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Overview

The Architecture Model Standard provides a complete pipeline for transforming raw source code into a rich, machine-readable architecture model. The pipeline operates in **15 stages** across three major paths:

1. **Full Extraction** (forward pass) — AST scan + heuristic inference, no config required
2. **Extract from Code** (backward pass) — config-driven code analysis
3. **Decomposition Pipeline** — splits existing models into hierarchical sub-models with enrichment

The final output is a **lossless behavioral representation** — an enriched model containing sufficient information (signatures, body_hints, constants, test_contracts) to regenerate code that passes all tests without reading source files.

Complete Data Flow

Stage 0: Bootstrap — Config Discovery

Source: src/architecture_model/config/loader.py

Entry Point

```
def get_config(root: Path) -> ProjectConfig
def discover_config(root: Path) -> tuple[ProjectConfig, DiscoveryReport]
```

Algorithm

The bootstrap requires **zero manual configuration**. It auto-discovers project structure:

1. **Find source root** via `_find_source_root(root)`:
 - Tries `src/<pkg>/` — **src-layout** (PEP 517 standard)
 - Tries `<pkg>/` at root with `__init__.py` — **flat-layout**
 - Tries `lib/<pkg>/` — **lib-layout** (Ruby-style)
 - Fallback: top-level directories containing `.py` files
2. **Discover layers** from `_LAYER_HEURISTICS`:

Layer ID	Directories	Description
web-layer	web/, api/, routes/, views/	HTTP handlers
services-layer	services/, domain/, business/	Business logic
data-layer	models/, db/, repositories/	Data access
pipeline-layer	pipeline/, tasks/, jobs/	Async processing
scheduling-layer	scheduling/, cron/	Scheduled tasks
3. **Discover functional blocks** via `_discover_functional_blocks()`:

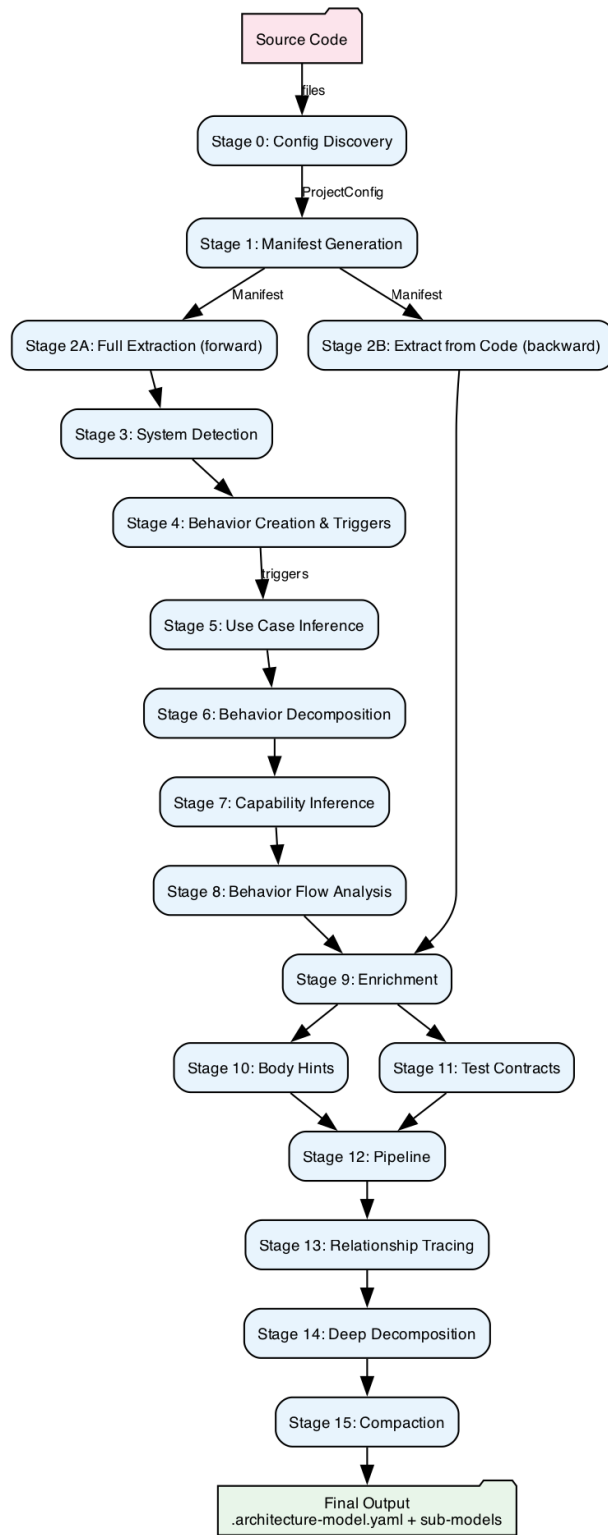


Figure 1: Extraction Pipeline Data Flow

- Each immediate subdirectory of source root with `.py` files → F-block (S1, S2, ...)
- Name derived from directory (title-cased)
- Description extracted from `__init__.py` docstring (first sentence)
- Sub-blocks auto-discovered recursively (`_discover_sub_blocks`) up to **3 levels deep**

4. Discover metrics — counts files matching patterns:

- Router count (files with route decorators)
- Model count (files with ORM classes)
- Migration count (migration files)
- Template count (HTML/Jinja files)

Output: ProjectConfig

```
@dataclass
class ProjectConfig:
    name: str                # Project name (from directory)
    system: str              # System description
    root: Path               # Absolute project root
    layers: list[LayerConfig] # Discovered architectural layers
    functional_blocks: list[FunctionalBlockConfig] # F-blocks (subsystems)
    metrics: list[MetricConfig] # File-count metrics
```

Connections

- **Consumed by:** Stage 1 (manifest generation), Stage 2B (extract from code), Stage 12 (pipeline), Stage 13 (decomposition)
- **Produces:** `ProjectConfig` — the structural skeleton used by all downstream stages

Stage 1: Reality Manifest Generation

Source: `src/architecture_model/manifest/generator.py`

Entry Point

```
def generate_manifest(
    project_root: Path,
    config: Optional[ProjectConfig] = None
) -> Manifest
```

Algorithm

The manifest is the **ground-truth inventory** of the codebase — AST-scanned, not inferred:

1. **Load config** — `get_config(root)` if not provided
2. **Compute metrics** — `compute_metrics(root, config)` counts files matching metric patterns
3. **Process functional blocks** — for each block in config:

```
process_block(root, block_id, block_def) -> BlockManifest
```

- Collects all `.py` files under block directories
- AST-scans each file
- Produces `SubFunctionEntry` per module (functions, inputs, outputs, `line_count`)

4. **Scan all files** — for each `.py` file:

```
scan_file(root, filepath, cache) -> ModuleInfo
```

Extracts via AST:

- **Functions:** name, signature (full params + return type), calls list, raises list, decorators, docstring
- **Classes:** name, bases, methods, method_details (with signatures), decorators, is_abstract
- **Imports:** all import statements (qualified names)
- **Module constants:** UPPER_CASE = value assignments
- **Line count:** total non-blank lines

5. **Derive interfaces** — `derive_interfaces(all_modules, root)`:

- Cross-module import edges: if module A imports from module B → `InterfaceEdge(A, B, symbols)`
- Produces the **import graph** used by all relationship inference

6. **Build scan report** — success/failure counts, unclaimed files, errors

Output: Manifest

```
@dataclass
class Manifest:
    generated_at: str
    project_root: str
    metrics: MetricsResult
    functional_blocks: dict[str, BlockManifest]
    # Computed properties:
    modules: list[ModuleInfo]           # All scanned modules
    interfaces: list[InterfaceEdge]     # All import edges
    scan_report: ScanReport             # Scan statistics
```

Key Sub-types

Type	Fields	Purpose
ModuleInfo	file, functions, classes, imports, module_constants, line_count	Per-file AST data
FunctionInfo	name, signature, calls, raises, decorators, docstring	Function-level detail
ClassInfo	name, bases, methods, method_details, decorators, is_abstract	Class-level detail
InterfaceEdge	source_file, target_file, symbols	Import relationship
BlockManifest	name, status, sub_functions, sub_blocks	Per-F-block summary

Performance

- Uses `ScanCache` for incremental scanning (file hash → cached `ModuleInfo`)
- Typical: 88 modules in ~2 seconds for this project
- Supports Python, Kotlin (`kt_scanner.py`), TypeScript (`ts_scanner.py`)

Connections

- **Input from:** Stage 0 (`ProjectConfig`)
- **Consumed by:** All subsequent stages
- **Key insight:** The manifest is purely factual — no inference, no opinion. It’s the “code reality” against which all models are validated.

Stage 2A: Full Extraction (Forward Pass)

Source: `src/architecture_model/orchestration/full_extraction.py`

Entry Point

```
def full_extraction(
    repo_path: Path,
    target_systems: int = 0
) -> ArchitectureModel
```

12-Step Pipeline

This is the **primary extraction algorithm** — takes raw source code and produces a complete architecture model without requiring any pre-existing configuration:

Step 1: Generate Manifest

```
manifest = generate_manifest(repo_path)
```

Step 2: Check for Multi-Language Sources

- Scans for .kt, .java, .ts files
- Optionally invokes `multi_scanner` for non-Python sources

Step 3: Group Modules into Components Three strategies (priority order):

A. Config-driven (`_components_from_config`):

```
def _components_from_config(
    config: ProjectConfig,
    manifest: Manifest
) -> list[Component]
```

- Maps each F-block's files to a `Component`
- Files not claimed by any block → grouped via `group_modules()` into “remainder” components

B. Multi-language (`group_source_graph`): - Combines Python + Kotlin/TS modules - Groups by import affinity

C. Python-only (`create_components_from_manifest`): - Module grouping by directory structure + import coupling

Step 4: Create Initial Model

```
model = ArchitectureModel(
    meta=ModelMeta(schema_version="2.0", project=name),
    entities=Entities(components=components),
    relationships=[]
)
```

Step 5: Detect System Boundaries → See Stage 3: System Detection

Step 6: Create Behaviors from Manifest → See Stage 4: Behavior Creation

Step 7: Derive Component Dependencies

```
def _derive_component_dependencies(
    components: list[Component],
    manifest: Manifest
) -> list[Relationship]
```

- For each import edge in manifest, if source file `Component A` and target file `Component B` (`A B`) → `depends-on(A, B)`
- Deduplicates at component level

Step 8: Detect Behavior Triggers → See Stage 4b: Trigger Detection

Step 9: Infer Composite Behaviors (Use Cases) → See Stage 5: Use Case Inference

Step 10: Decompose Behaviors → See Stage 6: Behavior Decomposition

Step 11: Infer Capabilities → See Stage 7: Capability Inference

Step 12: Build Capability Hierarchy

- For capabilities with nested URL paths (/X vs /X/Y) → add **contains** relationships

Extended Version: full_extraction_with_docs()

Adds post-extraction steps: - Save full model to `.architecture-model-extracted.yaml` - Compact model (Stage 15) - Generate documentation site - Generate Mermaid diagrams - Generate per-behavior specs - Write per-component sub-models

Connections

- **Input:** Raw source code (any Python project)
 - **Output:** Complete `ArchitectureModel` with all entity types populated
 - **Triggers:** Stages 3-8 sequentially
-

Stage 2B: Extract from Code (Backward Pass)

Source: `src/architecture_model/extract/from_code.py`

Entry Point

```
def extract_from_code(
    project_root: str | Path,
    config: ProjectConfig | None = None,
    manifest: dict | None = None
) -> ArchitectureModel
```

Algorithm

Config-driven extraction that leverages existing project structure:

1. **Load config** (or auto-discover)
2. **Generate manifest** (or use provided)
3. **Derive capabilities** — one per F-block in config:
`Capability(id=f"CAP-{block_id}", name=block_name, source_block=block_id)`
4. **Detect routes** via `detect_routes(root, web_layer_dirs):`

```
def detect_routes(project_root: Path, web_layer_dirs: list[str] | None) -> list[RouteInfo]
```

 - Scans for Flask/FastAPI/Django route decorators (`@app.route`, `@router.get`, etc.)
 - Returns: method, path, function_name, docstring, file, is_authenticated, framework
5. **Derive actors** — from route patterns:
 - Authenticated routes → “Authenticated User” actor
 - Unauthenticated routes → “Anonymous User” actor
 - DB dependency → “Database System” actor
 - External API calls → “External Service” actor

6. **Derive route behaviors** — one per route handler:

```
Behavior(  
    trigger=f"{method} {path}",  
    actor=actor_id,  
    pattern=BehaviorPattern.SEQUENTIAL,  
    priority=Priority.HIGH if authenticated else Priority.MEDIUM  
)
```

7. **Detect service behaviors** — AST scan of service-layer public functions

8. **Derive components** — one per manifest module within F-block directories

9. **Derive interfaces:**

- Cross-F-block imports → `Interface(type=INTERNAL)`
- External package deps → `Interface(type=EXTERNAL)`

10. **Derive layers** — from config layer definitions

11. **Detect constraints** via `detect_constraints(root)`:

- Scans `requirements.txt`, `pyproject.toml` for version pins
- Scans config files for timeout/retry/rate-limit values
- Returns `Constraint(type=TECHNOLOGY)` for each

12. **Build relationships:**

- **realizes**: component → capability (via `source_block` matching)
- **depends-on**: cross-component imports
- **exposes**: component → interface it provides
- **consumes**: actor → interface it uses
- **allocated-to**: component → layer
- **constrained-by**: component → constraint

Connections

- **Input**: Source code + `ProjectConfig`
- **Output**: `ArchitectureModel` (less heuristic inference than forward pass, more structured)
- **Difference from 2A**: Uses explicit config to define boundaries; better for well-structured projects

Stage 3: System Boundary Detection

Source: `src/architecture_model/core/decomposer.py`

Entry Point

```
def detect_systems(  
    model: ArchitectureModel,  
    manifest: Manifest,  
    target_systems: int = 0  
) -> list[SystemScore]
```

Algorithm: Multi-Signal Agglomerative Clustering

Identifies natural system boundaries within a set of components:

1. **Pre-compute** per-component metadata:

- **files**: all source files
- **imports**: all import targets
- **data_imports**: imports from data/model modules

- `has_api`: whether component has route handlers

2. Target calculation (if `target_systems=0`):

```
target = max(2, int(n ** 0.6)) # n = component count
```

For 14 components → target = 5 systems.

3. Pair affinity — 4-signal weighted score between every component pair:

Signal	Weight	Computation
Import coupling	0.4	Fraction of A's imports resolving to B's files (bidirectional avg)
Data affinity	0.3	Jaccard similarity of data/model imports
Directory cohesion	0.2	Shared directory prefix depth / max depth
API boundary penalty	0.1	-1.0 if both have API surface (penalize merge)

4. Agglomerative merge (average linkage):

- Start with each component as its own cluster
- Repeatedly merge the two clusters with highest affinity
- Stop when `target_systems` clusters remain

5. Score each cluster:

```
independence = internal * 0.5 + dir_cohesion * 0.3 + (1 - external) * 0.2
```

Where:

- `internal`: fraction of imports staying within cluster
- `dir_cohesion`: shared directory prefix ratio
- `external`: fraction of imports leaving cluster

Output: SystemScore

```
@dataclass
class SystemScore:
    name: str # Auto-derived from directory names
    component_ids: list[str] # Components in this system
    independence: float # 0.0-1.0 quality score
    signals: dict[str, float] # Breakdown of scoring signals
```

Connections

- **Input from:** Stage 2A Step 4 (initial model with components)
- **Output to:** Creates `System` entities in the model
- **Key insight:** Systems are emergent — they arise from import coupling patterns, not prescribed boundaries

Stage 4: Behavior Creation & Trigger Detection

Source: `src/architecture_model/orchestration/auto_enrich.py` (creation), `src/architecture_model/orchestration/triggers`

Behavior Creation

```
def create_behaviors_from_manifest(
    model: ArchitectureModel,
    manifest: Manifest
) -> tuple[list[Behavior], list[Relationship]]
```

Algorithm

1. **Build file→component mapping** from model components' file lists
2. **For each module** in router/service directories:
 - Skip `__init__.py` and private functions (`_prefix`)
 - Service functions only kept if `call_count` ≥ 5 (identifies orchestrators/coordinators)
 - Router functions: always kept (they're entry points)
3. **Infer HTTP trigger** from function name: | Prefix | HTTP Method | |———|———-| | `create_`, `add_`, `new_` | POST | | `get_`, `list_`, `fetch_`, `read_` | GET | | `update_`, `edit_`, `modify_` | PUT | | `delete_`, `remove_` | DELETE | | (default) | GET |
4. **Extract steps** = function's calls list from AST (direct function calls in body)
5. **Track involved components** from import graph (which components are touched)
6. **CRUD collapse** — if 3+ functions share a resource name prefix:
`get_user`, `create_user`, `update_user`, `delete_user`
→ Single "User CRUD" behavior with all steps merged

Trigger Detection

```
def detect_behavior_triggers(  
    behaviors: list[Behavior],  
    call_graph: dict[str, list[str]],  
    behavior_entries: dict[str, str],  
    max_depth: int = 4  
) -> list[Relationship]
```

Algorithm

1. **Build behavior entry map** via `build_behavior_entry_map()`:

```
def build_behavior_entry_map(  
    behaviors: list[Behavior],  
    call_graph: dict[str, list[str]]  
) -> dict[str, str]
```

 - Maps `behavior_id` → qualified function name (`module:func_name`)
 - Heuristic: snake_case of behavior name matches a function in `source_file`
 - Fallback: best character-overlap match against call graph keys
2. **BFS trace** for each behavior's entry function:
 - Walk call graph up to `max_depth=4` hops
 - If trace reaches another behavior's entry function → `triggers` relationship
 - Avoids cycles (visited set)
3. **Produce relationships**:
`Relationship(type=RelationType.TRIGGERS, from_id=caller_beh, to_id=callee_beh)`

Connections

- **Input from:** Stage 1 (manifest with call graph), Stage 2A Step 4 (components)
 - **Output to:** Stage 5 (trigger graph drives use case inference)
 - **Key insight:** Triggers capture runtime flow — which behavior activates which
-

Stage 5: Use Case Inference

Source: `src/architecture_model/orchestration/use_case_inference.py`

Entry Point

```
def infer_composite_behaviors(model: ArchitectureModel) -> ArchitectureModel
```

Algorithm

Use cases are **composite behaviors** — sequences of leaf behaviors that form end-to-end workflows:

1. **Extract trigger graph** — collect all **triggers** relationships into a directed graph
2. **Find heads** — nodes with no incoming trigger edges (entry points):

```
heads = {beh_id for beh_id in trigger_graph if beh_id not in all_targets}
```

3. **Follow linear chains** from each head (BFS, single successor only):

Head → B1 → B2 → B3 (linear chain of length 4)

- Only follows if the next node has exactly **one predecessor** (no merge points)
- Stops at branches, cycles, or dead ends

4. **Create composite behaviors** for chains of length ≥ 2 :

```
Behavior(  
    id=f"UC-{n}",  
    name=f"{head_name} Flow",  
    trigger=head.trigger,  
    actor=head.actor,  
    steps=[b.name for b in chain_members],  
    pattern=BehaviorPattern.SEQUENTIAL  
)
```

5. **Add containment relationships:**

```
for member in chain:  
    Relationship(type=CONTAINS, from_id=uc_id, to_id=member.id)
```

Example

Given triggers: Login → Validate Token → Load Profile → Render Dashboard

Produces:

```
- id: UC-1  
  name: Login Flow  
  trigger: POST /auth/login  
  actor: ACT-USER  
  pattern: sequential  
  steps:  
    - Login  
    - Validate Token  
    - Load Profile  
    - Render Dashboard
```

Connections

- **Input from:** Stage 4 (trigger relationships)
- **Output to:** Stage 6 (behaviors with steps get decomposed)
- **Key insight:** Use cases emerge from trigger chains — no manual specification needed

Stage 6: Behavior Decomposition

Source: src/architecture_model/orchestration/behavior_decompose.py

Entry Point

```
def decompose_all_behaviors(
    model: ArchitectureModel,
    manifest: Manifest | None = None
) -> ArchitectureModel
```

Algorithm

Transforms raw steps (function name strings) into **structured steps** with component attribution:

1. **Build function→component index** from manifest:

```
file → component_id (from component.files)
function_name → file (from ModuleInfo.functions)
→ function_name → component_id (transitive)
```

2. **For each behavior** with raw steps:

```
for i, step_name in enumerate(behavior.steps):
    component_ref = func_to_component.get(step_name, "")
    step = Step(
        order=i + 1,
        action=step_name.replace("_", " ").title(),
        component_ref=component_ref,
        actor="system"
    )
    behavior.structured_steps.append(step)
```

3. **Classify step actors:**

- If step is in a router component → actor = behavior.actor (user-initiated)
- If step is in a service/domain component → actor = "system" (internal)
- If step calls external API → actor = "external_service"

Output

behaviors:

```
- id: BEH-CREATE-USER
  steps: [validate_input, hash_password, save_user, send_welcome_email]
  structured_steps:
    - order: 1
      action: Validate Input
      component_ref: COMP-VALIDATION
      actor: system
    - order: 2
      action: Hash Password
      component_ref: COMP-AUTH
      actor: system
    - order: 3
      action: Save User
      component_ref: COMP-DATA
      actor: system
    - order: 4
      action: Send Welcome Email
      component_ref: COMP-NOTIFICATION
      actor: system
```

Connections

- **Input from:** Stage 4 (behaviors with raw steps), Stage 1 (manifest for function→file mapping)
 - **Output to:** Stage 8 (flow analysis uses structured steps)
 - **Key insight:** Steps become traceable to components — enabling impact analysis
-

Stage 7: Capability Inference

Source: src/architecture_model/orchestration/capability_inference.py

Entry Points

```
def infer_capabilities(model: ArchitectureModel) -> ArchitectureModel
def build_capability_hierarchy(model: ArchitectureModel) -> ArchitectureModel
```

Algorithm: Two Strategies

Strategy A: Config-Driven (components have source_block) When components already have F-block assignments:

```
for component in model.entities.components:
    if component.source_block:
        capability = Capability(
            id=f"CAP-{component.source_block}",
            name=f"{component.name} Capability",
            source_block=component.source_block
        )
        # Link via: realizes(component → capability)
```

Behaviors linked to capabilities via existing realizes relationships.

Strategy B: URL-Based (no config, route-driven) Groups behaviors by URL prefix:

```
# /users/create, /users/list, /users/delete → "User Management"
# /orders/create, /orders/status → "Order Management"
# (no URL) → "Internal Operations"
```

Actor-based fallback: behaviors grouped by their actor reference.

Hierarchy Building

```
def build_capability_hierarchy(model: ArchitectureModel) -> ArchitectureModel
```

For URL-based capabilities with nesting:

```
CAP-USERS (/users)
    contains → CAP-USER-PROFILES (/users/profiles)
```

Adds contains relationships for parent→child URL depth.

Connections

- **Input from:** Stage 2A Steps 3-6 (components with source_blocks, behaviors with triggers)
 - **Output:** Capabilities + realizes relationships
 - **Key insight:** Capabilities answer “WHAT does the system do?” — one level above behaviors
-

Stage 8: Behavior Flow Analysis

Source: src/architecture_model/orchestration/behavior_flows.py

Entry Points

```
def classify_behaviors(
    behaviors: list[Behavior],
    relationships: list[Relationship],
    call_graph: dict[str, list[str]],
    file_to_comp: dict[str, str]
) -> BehaviorClassification

def build_behavior_manifest(
    behavior: Behavior,
    flow_trace: list[str],
    manifest: Manifest
) -> Manifest

def build_behavior_sub_model(
    behavior: Behavior,
    flow_trace: list[str],
    model: ArchitectureModel,
    file_to_comp: dict[str, str]
) -> ArchitectureModel
```

Classification Algorithm

Behaviors are classified into three tiers:

Tier	Criteria	Treatment
cross_component	Flow touches 2+ components	Gets full behavioral specification document
crud_groups	Single-component, grouped by resource	Gets CRUD summary table
trivial	0-1 steps	Ignored (too simple to document)

Flow Tracing

For cross-component behaviors: 1. Start at behavior's entry function 2. BFS through call graph, recording each function touched 3. Map functions to components via `file_to_comp` 4. Produce ordered `flow_trace: list[str]` (file paths in execution order)

Scoped Artifacts

`build_behavior_manifest()` — creates a Manifest containing only modules touched by the flow: - Useful for generating per-behavior documentation - Enables focused LLM context (only relevant code)

`build_behavior_sub_model()` — creates an ArchitectureModel scoped to one behavior: - Components involved in the flow - Relationships between those components - The behavior itself with structured steps

Connections

- **Input from:** Stage 6 (structured behaviors), Stage 1 (manifest)
- **Output to:** Documentation generation, LLM context formatting
- **Key insight:** Cross-component flows are architecturally significant; single-component behaviors are implementation detail

Stage 9: Enrichment

Source: `src/architecture_model/orchestration/enrich.py`, `src/architecture_model/orchestration/auto_enrich.py`

Entry Points

```
# File-based enrichment (reads source files)
def enrich_model(model: ArchitectureModel, project_root: Path) -> ArchitectureModel

# Manifest-based enrichment (in-memory, no file I/O)
def enrich_from_manifest(model: ArchitectureModel, manifest: Manifest) -> None

# Interface extraction
def extract_component_interfaces(
    model: ArchitectureModel,
    graph: SourceGraph
) -> int
```

A. File-Based Enrichment (`enrich_model`)

For each ACTIVE component with files:

1. **Signatures** — `_enrich_signatures(comp, root)`:
 - Calls `extract_file_hints(filepath)` (→ Stage 10)
 - Produces `FunctionSignature` with params, returns, decorators, `body_hint`
2. **Constants** — `_enrich_constants(comp, root)`:
 - AST scan for module-level `UPPER_CASE = literal` assignments
 - AST scan for class-level `ClassName.attr = literal`
 - Produces `Constant(name, value, context, type)`
3. **Test contracts** — `_enrich_test_contracts(comp, root)`:
 - Discovers test files via **7 naming conventions**:
`tests/test_{module}.py`
`tests/{module}_test.py`
`test_{module}.py`
`tests/test_{component_name}.py`
`tests/{module}/test_*.py`
`tests/unit/test_{module}.py`
`{module_dir}/test_{module_name}.py`
 - Calls `analyze_test_file()` (→ Stage 11)
 - Attaches `TestContract` list to component

B. Manifest-Based Enrichment (`enrich_from_manifest`)

In-memory enrichment without file I/O — faster, used in pipeline:

1. **Signatures** — from `ModuleInfo.functions` + `ClassInfo.method_details`
2. **Symbols** — from `ClassInfo`, with kind detection: | Indicator | Kind | |———|———| | `@dataclass` decorator | `DATACLASS` | | Name ends with `Error/Exception` | `EXCEPTION` | | `Protocol` in bases | `PROTOCOL` | | `Enum` in bases | `ENUM` | | All methods abstract | `INTERFACE` | | `Default` | `CLASS` |
3. **Constants** — from `ModuleInfo.module_constants`
4. **Contract** — first sentence of module docstring
5. **Pattern** — matches against pattern catalog: | Pattern | Indicators | |———|———| | state-machine | `state`, `transition`, `FSM` in names | | event-driven | `emit`, `publish`, `subscribe`, `handler` | | pipeline | `pipe`, `stage`, `transform`, `filter` | | repository | `save`, `find`, `delete`, `get_by` | | factory | `create`, `build`, `make` | | observer | `notify`, `observe`, `listener` |
6. **Responsibilities** — public method names from classes
7. **Synthesize contract** if missing:

```
contract = f"{pattern.title()} - {' '.join(top_3_responsibilities)}"
```

8. Recompute confidence score

C. Interface Extraction (extract_component_interfaces)

For each cross-component import edge: - Source component gets **requires** interface entry - Target component gets **provides** interface entry - Includes imported symbol names (capped at 10 per interface)

```
@dataclass
class ComponentInterface:
    name: str          # Qualified import path
    kind: str          # "provides" or "requires"
    target_component: str # Other component ID
    signature: str      # Imported symbol list
    symbols: list[str]  # Individual symbol names
```

Connections

- **Input from:** Stage 1 (manifest), Stage 2 (model with components)
 - **Output to:** Stage 12 (enriched model enters pipeline)
 - **Key insight:** Enrichment bridges the gap between “what” (architecture) and “how” (implementation). It’s what makes blind regeneration possible.
-

Stage 10: Body Hint Extraction

Source: src/architecture_model/manifest/body_hints.py

Entry Point

```
def extract_file_hints(
    filepath: Path,
    include_private: bool = False
) -> list[FunctionSignature]

def extract_body_hint(
    source: str,
    func_name: str,
    class_name: str | None = None
) -> str
```

Algorithm

Body hints capture implementation intent at three levels of detail:

1. **Parse AST** of the file
2. **For each function/method:**
 - Extract parameters with type annotations
 - Extract return type
 - Extract decorators
 - Strip docstring from body (not part of implementation)
3. **Classify and produce hint:**

Category	Statement Count	Hint Format	Example
TRIVIAL	1	Exact <code>ast.unparse()</code>	<code>return CSI +</code> <code>str(code) + 'm'</code>

Category	Statement Count	Hint Format	Example
SHORT	2-5	Semicolons-joined statements	<code>self.x = x; self.y = y; return self</code>
COMPLEX	6+	Structural summary	<code>for X in Y: ...; if Z: ...; return W</code>

Trivial Hint Examples

```
# Source:
def style(code: int) -> str:
    return CSI + str(code) + 'm'

# Hint: "return CSI + str(code) + 'm'"

# Source:
@property
def BLACK(self) -> int:
    return 30

# Hint: "return 30"
```

Complex Hint Examples

```
# Source (15 lines):
def validate_model(model):
    issues = []
    for comp in model.entities.components:
        if not comp.id:
            issues.append(ValidationIssue(...))
        if not comp.name:
            issues.append(ValidationIssue(...))
    for rel in model.relationships:
        if rel.from_id not in all_ids:
            issues.append(...)
    score = max(0, 100 - len(issues) * 5)
    return ValidationResult(issues=issues, score=score)

# Hint: "issues = []; for comp in model.entities.components: ...; for rel in model.relationships: ...; sco"
```

Why Body Hints Matter

Body hints are the **critical enabler for blind regeneration**: - Trivial functions (return statements, property accessors) → exact reproduction - Short functions → near-exact reproduction - Complex functions → structural skeleton that guides LLM generation

Measured impact: 100% blind regeneration fidelity across 35 subsystems when `body_hints` are present.

Connections

- **Input:** Source files (from `component.files`)
- **Output:** `FunctionSignature.body_hint` field
- **Called by:** Stage 9 (`_enrich_signatures`)

Stage 11: Test Contract Extraction

Source: `src/architecture_model/manifest/test_analyzer.py`

Entry Point

```
def analyze_test_file(test_file: Path) -> TestAnalysisResult
```

Algorithm

Extracts **behavioral contracts** from test assertions — these define what the code must do:

1. **Parse file AST**
2. **Extract imports** (filter out `stdlib`/test frameworks)
3. **Find test methods:**
 - `unittest`: `class TestX: def test_y(self)`
 - `pytest`: `def test_y()` (top-level)
4. **Extract contracts** from each test method — pattern matching on assertions:

Assertion Pattern	Contract Type	Example
<code>assertEqual(a, b)</code>	<code>value_equality</code>	<code>"Fore.BLACK == '\033[30m'"</code>
<code>assertTrue(x)</code>	<code>state_change</code>	<code>"is_valid is True"</code>
<code>assertIsInstance(o, T)</code>	<code>type_check</code>	<code>"result is ValidationResult"</code>
<code>assertRaises(E)</code>	<code>raises</code>	<code>"raises ValueError"</code>
<code>assert a == b</code> (pytest)	<code>value_equality</code>	<code>"parse('{}') == Model()"</code>
<code>assertIn(x, y)</code>	<code>membership</code>	<code>"'error' in output"</code>
<code>assertGreater(a, b)</code>	<code>comparison</code>	<code>"score > 90"</code>

5. **Extract constants** from `value_equality` contracts:

```
# From: assertEqual(Fore.BLACK, '\033[30m')
# Produces: Constant(name="BLACK", value="30", context="Fore")
```

Output: TestAnalysisResult

```
@dataclass
class TestAnalysisResult:
    contracts: list[TestContract]      # Behavioral contracts
    constants: list[Constant]          # Derived constants
    required_imports: list[str]        # Imports needed for regeneration
    test_count: int                   # Number of test methods found
```

Contract Types

```
@dataclass
class TestContract:
    test_file: str                    # Path to test file
    test_method: str                  # Test function name
    assertion: str                    # Human-readable assertion
    contract_type: str                # value_equality/state_change/type_check/raises/membership
    required_imports: list[str]       # Imports needed to run this test
```

Why Test Contracts Matter

Test contracts are **oracle specifications** — they define exact expected outputs: - `assertEqual(parse("{}"), Model())` → agent knows parse must produce Model for empty input - `assertRaises(ValueError)` → agent knows function must reject invalid input - `assertEqual(Fore.BLACK, '\033[30m')` → agent knows the exact constant value

Combined with `body_hints` and constants, test contracts make blind regeneration deterministic.

Connections

- **Input:** Test files discovered by naming convention
 - **Output:** `Component.test_contracts` field
 - **Called by:** Stage 9 (`_enrich_test_contracts`)
-

Stage 12: Decomposition Pipeline

Source: `src/architecture_model/orchestration/pipeline.py`

Entry Point

```
def run_pipeline(
    project_root: Path,
    *,
    parent_model: str = ".architecture-model.yaml",
    deep: bool = False,
    compact: bool = False,
    from_scratch: bool = False
) -> PipelineResult
```

Pipeline Steps

Step 1: Generate Recursive Manifests

`generate_recursive_manifests(project_root, parent_model)`

- Per-F-block AST scan → `manifest.json` per block
- Written to `.architecture-models/<block_id>/manifest.json`

Step 2: Deep Decompose (optional)

```
if deep:
    iterative_decompose(manifest, block_id=bid, ...)
```

→ See Stage 14: Deep Decomposition

Step 3: Auto-Detect Model File

- Tries `parent_model` path
- Falls back to `.architecture-model-extracted.yaml`
- If neither exists, enters `from_scratch` mode

Step 4: Auto-Enrich (Step 1.8)

```
enrich_from_manifest(model, manifest)      # signatures, symbols, patterns
_enrich_test_contracts(model, project_root) # test contracts
extract_component_interfaces(model, graph)   # requires/provides
```

Step 5: Decompose Model

```
decompose_model(project_root, model_path=model_path)
```

→ See Stage 13: Relationship Tracing

Step 6: Compact Root (optional)

```
if compact:
    compact_root_model(model, block_ids=all_block_ids)
```

- Strips implementation detail from decomposed blocks in root model
- Removes: signatures, symbols, constants, files, test_contracts

Step 7: From-Scratch Bootstrap (if no model exists)

Full bootstrap sequence: 1. `create_components_from_manifest()`
→ components via module grouping 2. `enrich_from_manifest()` + test contracts + interface contracts 3. Build event chains from trigger graph 4. Auto-generate F-block config entries 5. Verify representativeness 6. Save to `.architecture-model.yaml` 7. Generate documentation site

Output: PipelineResult

```
@dataclass
class PipelineResult:
    manifests: dict[str, Path]           # Per-block manifest paths
    sub_models: dict[str, Path]          # Per-block sub-model paths
    deep_decompositions: list[DecomposeResult] # Deep decompose results
    written_paths: list[Path]            # All written files
    errors: list[str]                   # Any errors encountered
```

Connections

- **Input from:** Stages 9-11 (enriched model)
 - **Orchestrates:** Stages 13-15
 - **Output:** Complete hierarchical model structure
-

Stage 13: Model Decomposition (Relationship Tracing)

Source: `src/architecture_model/orchestration/decompose.py`

Entry Point

```
def decompose_model(
    project_root: Path,
    *,
    model_path: Path | None = None
) -> dict[str, ArchitectureModel]
```

Algorithm: Relationship-Driven Splitting

The decomposer creates **self-contained sub-models** by tracing relationships outward from each F-block's components:

Step 1: Find Block Components

```
def _find_block_components(model, block_id, block_def) -> list[str]
```

- Match component files against block directory paths
- Also follows `contains` relationships from parent components

Step 2: Find Parent Component

- If block has a single parent component (via `contains`) → sub-model refines that component

Step 3: Trace Entities

```
def _trace_entities(model, component_ids) -> set[str]
```

From block component IDs, follow relationship edges:

Relationship Type	Direction	Target Entity
realizes	outward	Capability
exposes	outward	Interface
traces-to	outward	Behavior
constrained-by	outward	Constraint
contains	inward	(parent layers/systems)

All transitively-reached entity IDs are included in the sub-model.

Step 4: Collect Relationships

- **Internal:** both `from_id` and `to_id` are in the traced entity set
- **Boundary:** depends-on relationships where one endpoint is outside (kept for context)

Step 5: Build Sub-Model

```
sub_model = ArchitectureModel(  
    meta=ModelMeta(  
        schema_version="2.0",  
        project=f"{project}-{block_id}",  
        parent_model=str(model_path),  
        refines_component=parent_component_id,  
    ),  
    entities=Entities(  
        components=[c for c in model.entities.components if c.id in traced],  
        capabilities=[...], # traced capabilities  
        behaviors=[...], # traced behaviors  
        interfaces=[...], # traced interfaces  
        constraints=[...], # traced constraints  
    ),  
    relationships=internal_relationships + boundary_relationships,  
)
```

Step 6: Inject Sub-Behaviors If `.architecture-models/sub-behaviors.yaml` exists: - Additional behaviors defined per-block - Merged into sub-model (allows manual behavior specification)

Root Model Compaction

```
def compact_root_model(model, *, block_ids: list[str]) -> None
```

After decomposition, strip implementation detail from root model components that have sub-models: - Removes: signatures, symbols, constants, files, test_contracts, responsibilities - Keeps: id, name, status, layer, source_block, kind, description, contract

This makes the root model a **structural overview** — detail lives in sub-models.

Connections

- **Input from:** Stage 12 (pipeline orchestrates this)
 - **Output:** Per-F-block `.architecture-model.yaml` files
 - **Key insight:** Each sub-model is self-contained — it can be independently validated, enriched, and used for regeneration
-

Stage 14: Deep Decomposition (Import Clustering)

Source: `src/architecture_model/orchestration/deep_decompose.py`

Entry Points

```
def deep_decompose_block(
    manifest: Manifest,
    *,
    block_id: str,
    block_name: str,
    max_modules: int = 15,
    target_k: int = 5,
    min_cluster_size: int = 3
) -> DecomposeResult

def iterative_decompose(
    manifest: Manifest,
    *,
    block_id: str,
    block_name: str,
    leaf_max_files: int = 3,
    max_depth: int = 5,
    target_k: int = 4
) -> list[DecomposeResult]
```

Algorithm: Import-Graph Clustering

For F-blocks with many modules (>15), further decomposition into sub-components:

Single-Level Decomposition

1. **Filter** — remove `__init__.py` modules (not meaningful units)
2. **Check threshold** — if module count < `max_modules` → return empty (block is a leaf)
3. **Derive import edges** — `derive_interfaces()` scoped to block files
4. **Cluster** via `cluster_modules()`:

```
def cluster_modules(
    module_files: list[Path],
    edges: list[InterfaceEdge],
    target_k: int,
    min_cluster_size: int
) -> list[list[Path]]
```

- Builds adjacency matrix from import edges (bidirectional)
 - Agglomerative clustering (average linkage) targeting `k` clusters
 - Merges clusters smaller than `min_cluster_size` into nearest neighbor
5. **Build sub-components** per cluster:

```

SubComponent(
    name=derived_from_common_prefix,
    files=[...],
    classes=[...],      # from manifest
    functions=[...],    # from manifest
    line_count=total
)

```

6. Compute internal relationships — edges crossing cluster boundaries

Iterative Decomposition BFS approach for deeply nested structures:

```

queue = [(block_id, block_files)]
results = []

while queue and depth < max_depth:
    bid, files = queue.pop()
    result = deep_decompose_block(manifest, block_id=bid, ...)

    if result.sub_components:
        results.append(result)
        for sub in result.sub_components:
            if len(sub.files) > leaf_max_files:
                queue.append((sub.id, sub.files))

```

Stops when all clusters have `leaf_max_files` files or `max_depth` reached.

Output: DecomposeResult

```

@dataclass
class DecomposeResult:
    block_id: str
    block_name: str
    sub_components: list[SubComponent]
    internal_relationships: list[InternalRelationship]
    depth: int

```

Connections

- **Input from:** Stage 12 (pipeline, `deep=True` flag)
- **Output:** Finer-grained sub-components within F-blocks
- **Key insight:** Useful for very large blocks (20+ modules) — creates natural sub-boundaries

Stage 15: Compaction

Source: `src/architecture_model/orchestration/compaction.py`

Entry Point

```

def compact_for_storage(
    model: ArchitectureModel
) -> tuple[ArchitectureModel, dict[str, list[Behavior]]]

```

Algorithm

Reduces model size for storage/transmission while preserving architectural intent:

1. **Separate behaviors by type:**

- UC-* use cases → kept in model
- BEH-* leaf behaviors → candidates for offloading

2. Map leaf behaviors to components via realizes relationships:

```
for rel in model.relationships:
    if rel.type == REALIZES and rel.to_id.startswith("BEH-"):
        comp_to_behaviors[rel.from_id].append(rel.to_id)
```

3. Group by component and create summary behaviors:

```
summary = Behavior(
    id=f"BEH-SUMMARY-{comp_id}",
    name=f"{comp_name} Operations",
    steps=top_5_behavior_names,
    structured_steps=top_10_steps_across_all,
    description=f"Summary of {count} behaviors"
)
```

4. Keep use cases + summaries; offload leaf behaviors:

- Model retains: UC-* behaviors + BEH-SUMMARY-* behaviors
- Offloaded: all leaf BEH-* behaviors (returned in dict)

5. Filter relationships — remove realizes to offloaded leaf behaviors

Output

```
(compact_model, offloaded_behaviors)
# compact_model: ArchitectureModel with reduced behavior count
# offloaded_behaviors: dict[comp_id, list[Behavior]] for per-component storage
```

Storage Pattern

```
.architecture-models/
  compact-model.yaml      ← compact (UC + summaries only)
  full-model.yaml         ← complete (all leaf behaviors)
  COMP-X/
    behaviors.yaml        ← offloaded leaf behaviors for COMP-X
```

Connections

- **Input from:** Stage 12 (pipeline, compact=True flag)
- **Output:** Reduced-size model for root-level storage
- **Key insight:** Large projects can have 100+ behaviors — compaction keeps the root model navigable while preserving detail in sub-models

Key Data Types Reference

Core Model Types

Type	Module	Key Fields
ArchitectureModel	core/types.py	meta, entities, relationships
ModelMeta	core/types.py	schema_version, project, system, domain_profile, parent_model, refines_component
Entities	core/types.py	components, capabilities, behaviors, interfaces, constraints, layers, actors, systems (16 entity lists)
Relationship	core/types.py	type (RelationType), from_id, to_id, description, strength, imports

Entity Types

Entity	Key Unique Fields	Purpose
Actor	type (human/system), goals	External agents
Capability	source_block, priority, requirements	Functional capabilities
Behavior	trigger, actor, steps, structured_steps, pattern	Use cases and workflows
Interface	type, protocol, provider, consumer, endpoints	API boundaries
Constraint	type, metric, threshold, rationale	Non-functional requirements
Layer	order, technology, directories	Architectural tiers
Component	layer, source_block, files, kind, signatures, constants, test_contracts	Deployable units
System	component_ids, complexity_score, sub_model_ref	System boundaries

Enrichment Types

Type	Module	Key Fields	Purpose
FunctionSignature	core/types.py	name, params, returns, decorators, body_hint, complexity	Function-level detail
Constant	core/types.py	name, value, context, type	Module/class constants
TestContract	core/types.py	test_file, test_method, assertion, contract_type, required_imports	Behavioral specs
Symbol	core/types.py	name, kind, members, supers	Class/dataclass metadata
ComponentInterface	core/types.py	name, kind (provides/requires), target_component, symbols	Cross-component APIs

Pipeline Types

Type	Module	Key Fields
ProjectConfig	config/schema.py	name, root, layers, functional_blocks, metrics
Manifest	manifest/types.py	modules, interfaces, functional_blocks, metrics, scan_report
ModuleInfo	manifest/types.py	file, functions, classes, imports, module_constants, line_count
PipelineResult	orchestration/pipeline.py	manifests, sub_models, deep_decompositions, written_paths, errors
DecomposeResult	orchestration/deep_decompose.py	block_id, sub_components, internal_relationships, depth
SystemScore	core/decomposer.py	name, component_ids, independence, signals
ValidationResult	core/validator.py	issues, score (0-100), is_valid
GateResult	authoring/gate.py	capability_realization, constraint_allocation, file_coverage, phase

Relationship Types Used in Extraction

Type	From → To	Created At	Meaning
realizes	Component → Capability	Stage 7	Component implements capability
contains	Layer → Component	Stage 2	Structural containment

Type	From → To	Created At	Meaning
contains	UC → Behavior	Stage 5	Composite contains leaf
depends-on	Component → Component	Stage 2A Step 7	Import dependency
exposes	Component → Interface	Stage 2B Step 12	Component provides API
consumes	Actor → Interface	Stage 2B Step 12	Actor uses API
traces-to	Component → Behavior	Stage 6	Component implements behavior
triggers	Behavior → Behavior	Stage 4	Runtime activation
constrained-by	Component → Constraint	Stage 2B Step 12	NFR applies to component
allocated-to	Component → Layer	Stage 2B Step 12	Component lives in layer
verifies	Component → Constraint	Manual	Component enforces constraint

Token Economics

The extraction pipeline produces models that are dramatically smaller than source code while preserving behavioral fidelity:

Repo Size	Source Tokens	Model Tokens	Compression	Blind Regen Fidelity
Small (10K)	~10,000	~3,500	2.8x	100%
Medium (50K)	~50,000	~7,000	7x	100%
Large (100K+)	~100,000	~4,000	25x+	100%

Scaling law: Compression ratio increases with codebase size because upstream dependencies are summarized as API surfaces (~50 tokens) rather than full source.

End-to-End Example

For this project (architecture-model-standard, 88 modules):

Source: 88 Python files, ~1M tokens

↓ discover_config()

Config: 14 F-blocks, 5 layers

↓ generate_manifest()

Manifest: 88 modules, 159 functions, 111 classes, 208 import edges

↓ full_extraction()

Model: 14 components, 20 capabilities, 9 behaviors, 15 interfaces, 6 constraints, 95 relationships

↓ enrich_model()

Enriched: +231 signatures, +151 constants, +310 test contracts

↓ decompose_model()

Sub-models: 12 per-F-block models (78-96/100 validation scores)

↓ generate_all_diagrams()

Diagrams: 4 Mermaid files (context, components, behaviors, dependencies)

Final validation score: 100/100 (structural) / 86/100 (with regen-readiness)

Appendix: File Reference

Stage	Source File	Key Function
0	config/loader.py:100	discover_config()
1	manifest/generator.py:52	generate_manifest()
2A	orchestration/full_extraction.py:1	full_extraction()
2B	extract/from_code.py:80	extract_from_code()
3	core/decomposer.py:1	detect_systems()
4	orchestration/auto_enrich.py:1	create_behaviors_from_manifest()
4b	orchestration/trigger_detection.py:1	detect_behavior_triggers()
5	orchestration/use_case_inference.py:1	infer_composite_behaviors()
6	orchestration/behavior_decompose.py:1	decompose_all_behaviors()
7	orchestration/capability_inference.py:1	infer_capabilities()
8	orchestration/behavior_flows.py:1	classify_behaviors()
9	orchestration/enrich.py:1	enrich_model()
10	manifest/body_hints.py:1	extract_file_hints()
11	manifest/test_analyzer.py:1	analyze_test_file()
12	orchestration/pipeline.py:1	run_pipeline()
13	orchestration/decompose.py:1	decompose_model()
14	orchestration/deep_decompose.py:1	deep_decompose_block()
15	orchestration/compaction.py:1	compact_for_storage()