ANTHROPIC SOLUTION ENGINEERING

Building Intelligent Agents with Claude Agent SDK

Architecting the "Rei" Engine in Python

PYTHON SDK | AGENTIC WORKFLOW | ENTERPRISE HARNESS

The Shift: Chat vs. Agents

Stateless Chat

Standard API interactions are stateless. You send a prompt, you get a completion. Logic lives in your application code.

- ✕ Complex state management on client
- ✕ Tool execution requires external loops
- ✕ Hard to "contain" mid-flight

The Agentic Model (SDK)

The SDK brings the "Loop" inside. It allows Claude to:

- **Plan & Reason**
- **Execute Tools (In-Process)**
- **Adhere to Safety Hooks**

What is the Claude Agent SDK?

It is not just a wrapper around the Messages API. It is the **engine** that powers Claude Code.

It provides a standardized harness for building agents that can:

- Execute terminal commands safely
- Edit files with permissioning
- Maintain persistent context
- Fork sessions for exploration

The Bundle

The Python SDK automatically bundles the **Claude Code CLI** binary.

No separate Node.js or binary installation required. `pip install` handles the binary fetch and setup.

The Stack Decoded

To understand the SDK, we must distinguish between the components.

1. Python Script

Your Entry Point. The `main.py` you write. It imports the SDK and initiates the connection.

2. Python App

The Wrapper. The larger ecosystem hosting your script (FastAPI, Django, or CLI).

3. The Agent

The Logic. The `ClaudeSDKClient` instance. Holds state and handles the "Loop".

4. The CLI Binary (The Engine)

A pre-compiled binary (managed by the SDK) that runs as a subprocess. Handles API communication, tokenization, and sandboxed execution.

Visualizing the Harness

The SDK acts as a bridge between your application logic and the Anthropic execution engine.

Control Protocol

A JSON-RPC style protocol flows over the transport layer, handling interrupts, permissions, and tool calls.

Isolation

If the Agent generates a "crash" (e.g., runs a bad bash command), it happens in the Subprocess, protecting your main Python App.

Getting Started

Installation & Basic Concepts

Installation & Prerequisites

Requirements

- Python 3.10+
- Valid Anthropic API Key

Setup

```
pip install claude-agent-sdk
```

Note: The SDK will automatically download the platform-specific Claude Code CLI binary during the first run or build process.

Environment Variables

```
export ANTHROPIC_API_KEY="sk-...
```

The SDK uses this key to authenticate the underlying bundled CLI against the Anthropic API.

Hello World: The query( ) Function

For simple, one-shot interactions where you don't need complex state management.

```
import anyio
from claude_agent_sdk import query, AssistantMessage, Te

async def main():
    # Simple one-shot query
    async for message in query(prompt="What is 2 + 2?"):
        if isinstance(message, AssistantMessage):
            for block in message.content:
                if isinstance(block, TextBlock):
                    print(block.text)

anyio.run(main)
```

Key Characteristics

- **Unidirectional:** Send prompt, stream response.
- **Stateless:** Each query is a fresh start (unless session ID is managed).
- **Async Iterator:** Yields messages as they arrive.

The Control Center: `ClaudeAgentOptions`

This object controls the environment, permissions, and capabilities of the agent.

Context & Identity

- `system_prompt`
- `cwd` (Working Directory)
- `model` (e.g., Sonnet 3.5)

Safety & Limits

- `max_budget_usd`
- `max_turns`
- `permission_mode`

Capabilities

- `allowed_tools`
- `mcp_servers`
- `hooks`

Defining the Working Environment

Agents interact with the filesystem. Setting the `cwd` is critical for file operations.

```
from pathlib import Path

options = ClaudeAgentOptions(
    # Set the root of the agent's world
    cwd="/path/to/project",

    # Define the persona
    system_prompt="You are a DevOps engineer."
)

# Pass options to query or client
await client.query("Check git status", options=options)
```

Sandbox Implications

By default, tools like `ls`, `grep`, or `Edit` will operate relative to this CWD.
The SDK ensures operations are grounded in this path.

Interactive Agents

The ClaudeSDKClient & State

The `ClaudeSDKClient`

Bidirectional & Stateful

Unlike `query()`, the Client maintains a persistent connection to the agent process.

- Send follow-up messages.
- Interrupt generation.
- Change settings mid-flight.
- Receive tool events and hooks.

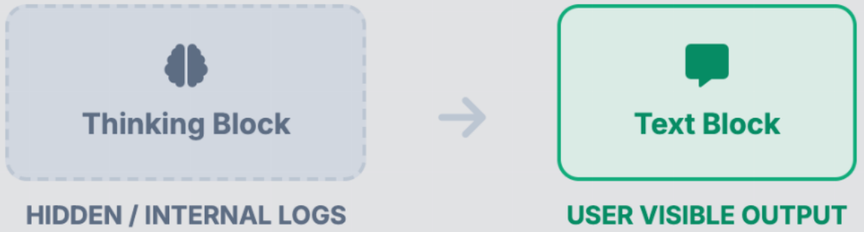
```
async with ClaudeSDKClient() as client:
    # First turn
    await client.query("Check the logs")
    async for msg in client.receive_response():
        print(msg)

    # Second turn (maintains context)
    await client.query("Fix the error you found")
    async for msg in client.receive_response():
        print(msg)
```

Streaming Deltas

To build rich UIs, you need to show the agent "typing" via `StreamEvent`.

```
options = ClaudeAgentOptions(
    include_partial_messages=True, # Enable deltas
)

async with ClaudeSDKClient(options=options) as client:
    await client.query("Write a story...")

    async for msg in client.receive_response():
        if isinstance(msg, StreamEvent):
            # msg.event contains: message_start,
            # content_block_delta, etc.
            delta = msg.event.get('delta', {})
            if delta.get('type') == 'text_delta':
                print(delta['text'], end="", flush=True)
```

Transparency: Auditing "Thinking"



Agents using **Extended Thinking** models produce reasoning steps before the final answer.

The SDK exposes these as `ThinkingBlock` objects, allowing you to audit the agent's logic chain.

```
if isinstance(msg, AssistantMessage):
    for block in msg.content:
        if isinstance(block, ThinkingBlock):
            # Hidden reasoning
            logger.info(f"Reasoning: {block.thinking}")

        elif isinstance(block, TextBlock):
            # Final output to user
            print(block.text)
```

Control Flow: Interrupts

Agents can get stuck in loops or go down wrong paths. The SDK allows you to signal an interrupt to the underlying process.

This stops the generation but keeps the session alive for a new prompt.

```
# Start a long running task
await client.query("Count to 1 million")

# ... some logic decides to stop it ...
await asyncio.sleep(2)

# Send interrupt signal
await client.interrupt()

# Send new instruction
await client.query("Actually, just count to 10")
```

Dynamic Runtime Control

You can change the agent's brain or permissions without restarting the session.

Switch Models

```
await client.set_model(
  "claude-3-5-haiku"
)
```

Swap to a faster/cheaper model for simple sub-tasks.

Change Permissions

```
await client.set_permission_mode(
  "acceptEdits"
)
```

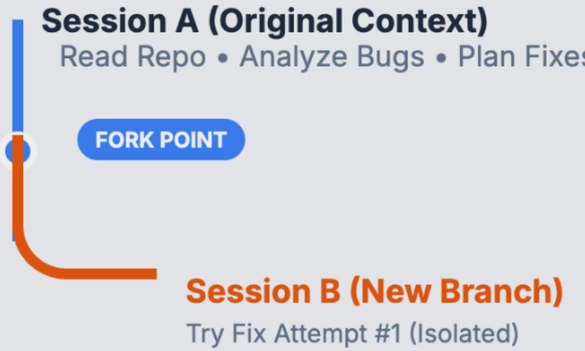
Grant write access dynamically after a review phase.

Budgeting

```
options.max_budget_usd = 0.50
```

Hard stop the agent if it burns too many tokens.

Session Forking



Exploration Pattern

Start a session, establish context (e.g., read a repo), and then "fork" the session to try multiple parallel experiments without re-reading the repo.

```
options = ClaudeAgentOptions(
    resume="session-id-123",
    fork_session=True
)

# This creates a NEW session ID but keeps
# the history of session-123.
async with ClaudeSDKClient(options) as client:
    await client.query("Try approach A")
```

Tools & MCP

The Agent's Hands and Eyes

Model Context Protocol (MCP)

MCP is the standard way to connect AI models to data and tools.

Instead of hardcoding API calls, you expose "Servers" that provide:

- **Tools:** Executable functions (e.g., "query_db")
- **Resources:** readable data (e.g., "logs://")
- **Prompts:** Reusable templates

Standardized Interface

Game Changer: In-Process MCP

Traditionally, MCP servers run as separate processes (stdio/SSE).
The SDK allows you to run MCP servers **directly inside your Python application**.

No Overhead

No IPC (Inter-Process Communication) serialization lag. Function calls are direct Python calls.

Shared State

Tools can access your app's global variables, database connections, and memory.

Simple Debugging

Set breakpoints in your tool code and step through it alongside your agent logic.

Tooling Pattern: Input Sanitization

You can intercept tool inputs before execution to "fix" or redirect them transparently.

This is crucial for sandboxing writes or preventing agents from touching forbidden directories without breaking the flow.

```
async def permission_callback(tool, input, context):
    if tool == "Write" and "forbidden" in input["file_path"]:
        # Redirect to safe location silently
        new_input = input.copy()
        new_input["file_path"] = "/tmp/safe_write.txt"

        return PermissionResultAllow(
            updated_input=new_input
        )
```

Architecture: External vs. In-Process

External (Standard MCP)

Mechanism: Spawns a new process (e.g., `node server.js`). Communicates via Stdio pipes.

- ✓ Isolated environment
- ✓ Language agnostic
- ✗ High latency (IPC)
- ✗ Hard to share state

In-Process (SDK)

Mechanism: Registers Python functions directly within the SDK client memory.

- ✓ Zero Latency
- ✓ Shared Memory Access
- ✓ Easy Debugging
- ! Python only (for now)

Why use In-Process MCP?

For Solution Engineers integrating Claude into existing platforms, In-Process is often superior.

Reuse Connections

Don't open a new DB connection for every tool call. Use your existing SQLAlchemy session.

Speed

Eliminating JSON serialization/deserialization over pipes saves milliseconds per turn.

Complexity

No need to package/dockerize a separate "server". It's just a module in your app.

Implementation: The `@tool` Decorator

Creating an In-Process server is as simple as decorating a Python function.

```
from claude_agent_sdk import tool, create_sdk_mcp_serve

# 1. Define the tool
@tool("get_user_data", "Fetch user info", {"user_id": st
async def get_user_data(args):
    # Direct access to your app logic
    user = await db.fetch_user(args['user_id'])
    return {
        "content": [{"type": "text", "text": str(user)}]
    }

# 2. Create the server
server = create_sdk_mcp_server(
    name="internal-api",
    tools=[get_user_data]
)
```

Key Concepts

- **Type Hints:** Used for validation.
- **Async:** Tools must be async functions.
- **Return Format:** Standard MCP content structure.

Pattern: Shared State Access

The killer feature: Your tool can see your application's memory.

```
class ApplicationState:
    def __init__(self):
        self.feature_flags = {"beta_access": False}

app_state = ApplicationState()

@tool("toggle_feature", "Toggle a feature flag", {"feature": str})
async def toggle_feature(args):
    # Modify state directly!
    feat = args['feature']
    app_state.feature_flags[feat] = not app_state.feature_flags.get(feat, False)
    return {"content": [{"type": "text", "text": "Flag updated"}]}

# The agent effectively has "Root Access" to this specific state object.
```

Concept: Zero-Latency State

Real-World Examples

Internal API Gateway

Expose your company's private microservices (User Service, Billing) as tools without building public wrappers.

RAG & Vector DB

Pass your pre-loaded Vector Search client into the tool. Agent queries Pinecone/Weaviate directly.

DevOps Control

Expose Kubernetes client methods to allow the agent to inspect pods running in the current cluster context.

Registering the Server

Once created, you pass the in-process server to the Agent Options.

```
options = ClaudeAgentOptions(
    # Register the server
    mcp_servers={"internal_tools": server},

    # Whitelist the tools you want available
    # Format: mcp__{server_name}__{tool_name}
    allowed_tools=["mcp__internal_tools__greet"]
)

async with ClaudeSDKClient(options=options) as client:
    await client.query("Greet Alice")
```

Hybrid Tooling Strategy

You can mix In-Process tools with External MCP servers.

Internal (SDK)

- Business Logic
- Database Writes
- App Control

External (Stdio/SSE)

- PostgreSQL MCP Server
- GitHub MCP Server
- Slack MCP Server

```
options = ClaudeAgentOptions(
    mcp_servers={
        "internal": sdk_server,
        "github": {"type": "stdio", "command": "docker", "args": [...] }
    }
```

Controlling Tool Access

Just because a tool exists doesn't mean the agent should use it freely. The SDK offers three levels of granularity.

tools

Definition

Defines the *existence* of tools. This registers them with the LLM but does not guarantee execution rights.

```
["Read", "Edit"]
```

allowed_tools

Auto-Approval

Bypasses the human-in-the-loop check. The agent can execute these immediately.

```
["mcp__read_logs"]
```

disallowed_tools

Hard Block

Prevents usage entirely, even if the model tries to call it. Useful for rigorous safety.

```
["Bash"]
```

The Harness

Hooks, Safety & Permissions

The Safety Harness: Hooks

Hooks allow you to intercept the agent loop at critical points.

They act as a **middleware layer** between Claude's intent and the actual execution.

Hook Types

- **PreToolUse:** Before a tool runs. (Block/Allow)
- **PostToolUse:** After a tool runs. (Validate)
- **UserPromptSubmit:** Before prompt goes to LLM.

Human-in-the-Loop: Async Hooks

Use **Async Hooks** to pause execution and wait for external validation (e.g., a human approval in Slack).

```
async def approval_hook(input_data, tool_id, context):
    # This keeps the connection open but pauses the agent loop
    return {
        "async_": True,  # Signal to SDK to wait
        "asyncTimeout": 300000 # 5 minutes timeout
    }

# Your application then handles the out-of-band approval
# and resumes the hook via the control protocol.
```

ENTERPRISE PATTERN | JIRA INTEGRATION | SLACK APPROVAL

Data Privacy: PII Redaction

Intercept user prompts **before** they are sent to the LLM to redact sensitive info.

```
import re

async def redact_pii(input_data, tool_id, context):
    prompt = input_data["prompt"]
    # Regex to find Credit Cards
    cleaned = re.sub(r'\b(?:\d[ -]*?){13,16}\b', '[REDACTED_CC]', prompt)

    return {
        "hookSpecificOutput": {
            "hookEventName": "UserPromptSubmit",
            # SDK sends modified prompt to Claude
            "prompt": cleaned
        }
    }
```

Data Safety: Output Auditing

Use `PostToolUse` to ensure tools aren't returning sensitive database dumps or API keys to the context window.

```
async def audit_tool_output(input_data, tool_id, context):
    response = str(input_data["tool_response"])

    if "sk-ant-" in response:
        return {
            "systemMessage": "API Key detected in output. Redacting.",
            # Modify the result the agent sees
            "hookSpecificOutput": {
                "hookEventName": "PostToolUse",
                "tool_response": "[API KEY REDACTED]"
            }
        }
    return {}
```

PreToolUse: Implementing Guardrails

Intercept a tool call before it executes to inspect arguments.

```
async def check_bash(input_data, tool_id, context):
    command = input_data["tool_input"].get("command", "")

    if "rm -rf" in command:
        return {
            "hookSpecificOutput": {
                "hookEventName": "PreToolUse",
                "permissionDecision": "deny",
                "permissionDecisionReason": "Destructive commands blocked."
            }
        }
    return {} # Allow
```

PostToolUse: Validation & Feedback

Inspect the output of a tool. If it failed or produced sensitive data, you can intervene.

```
async def validate_output(input_data, tool_id, context):
    response = input_data["tool_response"]

    if "Error" in str(response):
        return {
            "systemMessage": "Tool failed.",
            "hookSpecificOutput": {
                "hookEventName": "PostToolUse",
                "additionalContext": "Try checking the syntax."
            }
        }
    return {}
```

UserPromptSubmit: Context Injection

Inject secret context or instructions without the user typing them.

```
async def inject_context(input_data, tool_id, context):
    return {
        "hookSpecificOutput": {
            "hookEventName": "UserPromptSubmit",
            "additionalContext": "Current Time: 12:00 PM. User is Admin."
        }
    }
```

ROI & Usage Tracking

The `ResultMessage` contains precise cost and token usage data, essential for billing internal departments or calculating ROI.

$0.042

SESSION COST

```
async for msg in client.receive_response():
    if isinstance(msg, ResultMessage):
        print(f"Cost: ${msg.total_cost_usd}")
        print(f"Duration: {msg.duration_ms}ms")
        print(f"Tokens: {msg.usage}")

        # Log to DataDog / Prometheus
        metrics.record(msg.total_cost_usd)
```

Wiring it Together

Hooks are registered in `ClaudeAgentOptions` using `HookMatcher`.

```
from claude_agent_sdk import HookMatcher

options = ClaudeAgentOptions(
    hooks={
        "PreToolUse": [
            # Only run this hook for "Bash" tool
            HookMatcher(matcher="Bash", hooks=[check_bash]),
        ],
        "UserPromptSubmit": [
            # Run for all prompts
            HookMatcher(matcher=None, hooks=[inject_context])
        ]
    }
)
```

Advanced: `can_use_tool` Callback

For complex logic beyond simple blocking, use the global permission callback.

```
async def my_permission_callback(tool, input, context):
    if tool == "Write" and "/etc/" in input["file_path"]:
        return PermissionResultDeny(message="System write denied")

    # Example: Redirect write to /tmp/
    if tool == "Write":
        new_input = input.copy()
        new_input["file_path"] = "/tmp/safe.txt"
        return PermissionResultAllow(updated_input=new_input)
```

This allows **modifying the tool input** on the fly.

Enterprise Safety: Budgeting

Prevent runaway agents from consuming infinite tokens.

The SDK tracks usage and will terminate the session with a specific error subtype if the limit is breached.

$0.50

MAX BUDGET USD

```
options = ClaudeAgentOptions(
    max_budget_usd=0.50, # 50 cents limit
    max_turns=20         # 20 loop iterations max
)
```

Reliability: The Testing Pyramid

Unit Tests (Tools)

Test your `@tool` functions directly in Python. They are just async functions.

Integration (Mocked)

Mock the `Transport` layer to simulate Claude responses without hitting the API.

E2E (Real API)

Use the `@pytest.mark.e2e` pattern to run real agent loops against a sandbox.

```
@pytest.mark.e2e
async def test_agent_completes_task():
    # Real call to Anthropic API
    async with ClaudeSDKClient(options) as client:
        await client.query("Echo 'success'")
        # Assert tool was called via logs
```

Advanced Architectures

Sub-Agents & Orchestration

Defining Sub-Agents

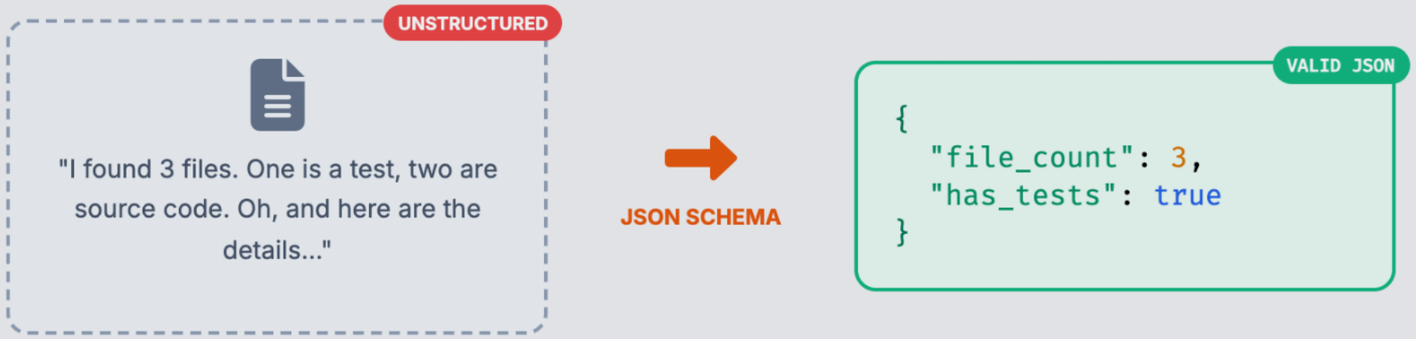
You can define specialized personas within the SDK. Claude can "handoff" tasks to these named agents.

```
from claude_agent_sdk import AgentDefinition

options = ClaudeAgentOptions(
    agents={
        "code-reviewer": AgentDefinition(
            description="Reviews code for security issues",
            prompt="You are a security auditor. Be strict.",
            tools=["Read", "Grep"],
            model="claude-3-opus"
        )
    }
)
```

The Orchestrator Pattern

The Main Agent uses the **"agents"** tool (automatically provided by SDK) to delegate work to the definitions provided in `AgentDefinition`.

Structured Output: From Chaos to JSON



The SDK forces the LLM to output only data that matches your strictly defined schema.

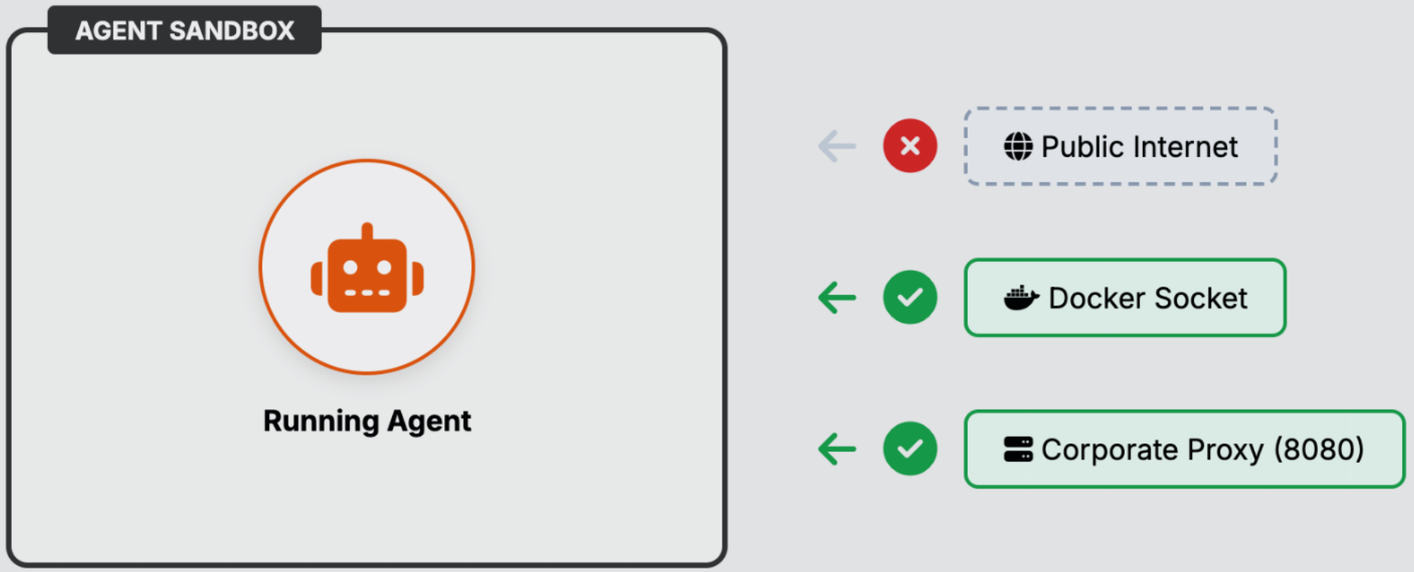
Security: Network Sandbox

Enterprise deployments often require strict network isolation. The `SandboxSettings` object controls exactly what the agent can access.

- Block all internet access.
- Allow specific Unix sockets (e.g., Docker).
- Force traffic through proxies.

```
sandbox_config = {
    "enabled": True,
    "network": {
        "allowAllUnixSockets": False,
        "allowUnixSockets": ["/var/run/docker.sock"],
        "httpProxyPort": 8080
    }
}

options = ClaudeAgentOptions(sandbox=sandbox_config)
```

Visualizing Network Isolation



Robust Error Handling

Production agents must handle failures gracefully. The SDK provides specific exception types.

CLINotFoundError

Agent runtime binary is missing or corrupt.

CLIConnectionError

The transport layer failed (process crash).

ProcessError

The underlying command exited with a non-zero code.

```
try:
    async for msg in query( ... ):
        pass
except CLIConnectionError:
    # Handle retry logic or fallback
    logger.error("Agent transport died, restarting ... ")
```

Settings Isolation

Control where Claude reads its configuration from. Vital for testing and secure environments.

User

Global settings (`~/.claude/`).

Project

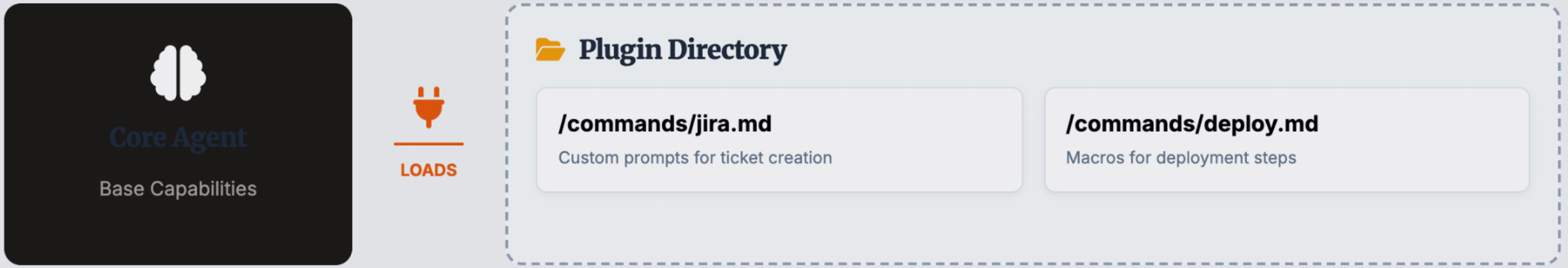
Repo settings (`./.claude/`).

Local

Git-ignored local overrides.

```
# Load NOTHING by default (Clean slate)
options = ClaudeAgentOptions(setting_sources=[])

# Load only User settings
options = ClaudeAgentOptions(setting_sources=["user"])
```

Plugins Architecture




```
options = ClaudeAgentOptions(
    plugins=[
        {
            "type": "local",
            "path": "/path/to/my/plugins"
        }
    ]
)
```

Debugging: The Stderr Callback

Since the CLI runs in a subprocess, you need a way to see its internal logs.

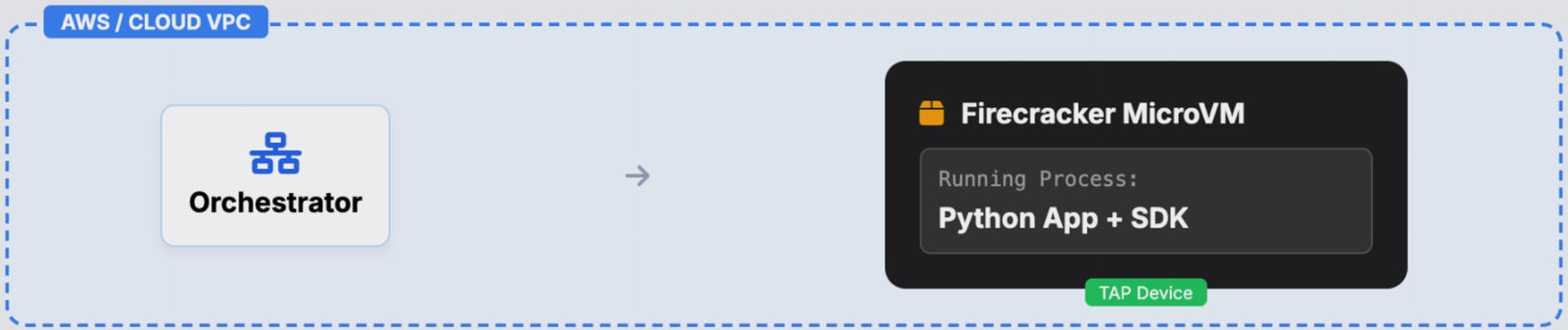
```
def my_logger(line):
    if "[ERROR]" in line:
        logger.error(line)
    else:
        logger.debug(line)

options = ClaudeAgentOptions(
    stderr=my_logger,
    extra_args={"debug-to-stderr": None} # Enable debug mode
)
```

Enterprise Deployment

Sandboxing & Production

Deep Sandboxing: Firecracker VMs

The SDK's internal sandbox protects the *filesystem*, but for running untrusted code from users, you need **Kernel Isolation**.



Requests enter via API Gateway, the Orchestrator spins up a dedicated MicroVM for the session. The SDK runs **inside** the VM, ensuring total isolation from the host.

Defense in Depth

Layering protections ensures maximum security for enterprise agents.

Layer 1: SDK Permissions

Controls what tools (Edit/Read) can be called. Prevents accidental file overwrites.

Layer 2: Bash Sandbox

SDK `SandboxSettings`. Restricts network access and blocks dangerous syscalls.

Layer 3: Firecracker/Docker

OS-level isolation. Prevents the agent from accessing host resources if Layer 1 & 2 fail.

Sandboxing (Bash)

The SDK supports configuring the Bash sandbox for file and network isolation.

```
sandbox_config = {
    "enabled": True,
    "network": {
        "allowUnixSockets": ["/var/run/docker.sock"],
        "allowLocalBinding": True
    },
    "excludedCommands": ["git"] # Git runs outside sandbox
}

options = ClaudeAgentOptions(sandbox=sandbox_config)
```

Note: Filesystem restrictions (Read/Write) are handled via Permissions, while Sandboxing handles process isolation.

Deployment Architecture

Containerization

Wrap your Python script + SDK in a Docker container. The SDK will pull the CLI binary inside the container.

Secret Management

Inject `ANTHROPIC_API_KEY` via environment variables. Do not hardcode.

Headless Mode

Use `query()` for background jobs. Use `ClaudeSDKClient` for WebSocket/API backends.

Build with Confidence

The Claude Agent SDK provides the harness you need to move from Chatbots to Autonomous Agents.

pip install claude-agent-sdk

docs.anthropic.com/en/docs/claude-code/sdk