Semiconductor (Chip) Design Workflow Orchestration with Airflow

3.0

Dheeraj Turaga | Senior Staff Engineer @ Qualcomm
Nicholas Redd | Senior Engineer @ Qualcomm

AIRFLOW SUMMIT

Semiconductor (Chip) Design Workflow Orchestration With Airflow

Dheeraj Turaga | Senior Staff CAD Engineer @ Qualcomm
Nicholas Redd | Senior Engineer @ Qualcomm

Agenda

- About Us
- Life Before Airflow
- Airflow @ Qualcomm
  - Dynamic Celery Workers
  - Multiple Executors: Celery + Edge
  - Multi DC Architecture
- Contributions
- Methodologies

About Us - Qualcomm

We make CPUs!

Qualcomm Oryon CPU – Our Snapdragon SOC Lineup :

Compute >

The industry leader in performance and power efficiency.

Mobile >

Transforming performance with the world's fastest mobile CPU.

Automotive >

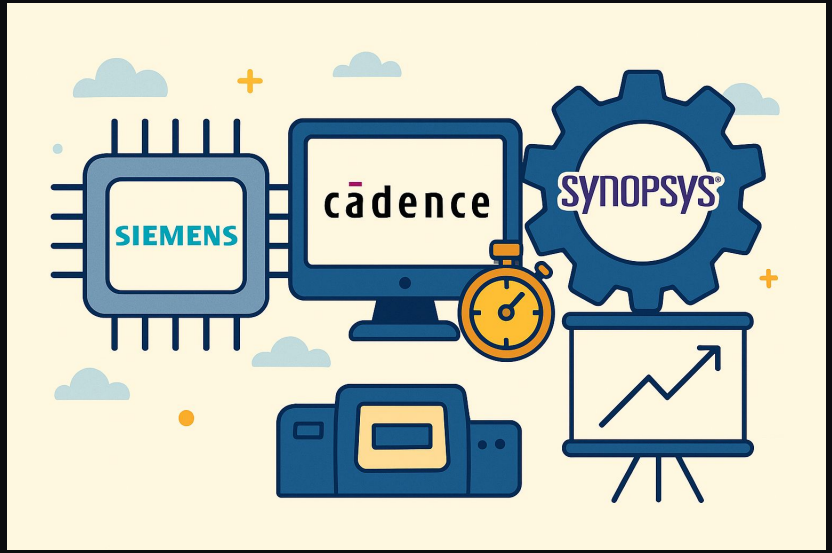
Unlocking a new era of automotive intelligence.

About Us – EDA Tools

EDA tools are specialized software used to automate and manage the complex processes of chip design and verification.

EDA tools demand:

- **Massive Compute:** tasks can run 7+ days, consume >256 GB RAM, generate 100s of GBs of output.
- **Rigid Vendor Constraints:** strict licensing, environment setup, and version dependencies
- **Scale of Orchestration:** Thousands of jobs must be scheduled and managed daily across multiple sites and compute grids.



EDA in Docker?

Requires Root Privileges → Security risk on multi-user clusters.

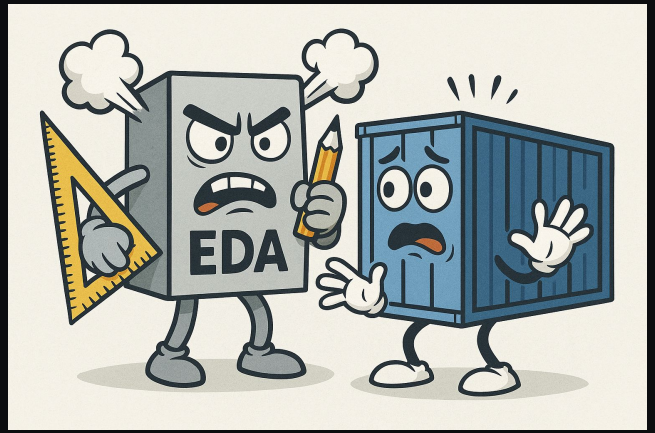
No Native Scheduler Integration → Hard to enforce resource limit policies.

OverlayFS Overhead → Slows down I/O-heavy EDA flows (millions of small files).

Limited Shared Memory & Ulimits → Manual tweaks needed; admins restrict flags.

Complex HPC Networking → MPI, Infiniband need extra config.

Unstable Host Identity → Breaks FlexNet licensing.



SLURM/LSF + Singularity

SLURM/LSF = Job Scheduler , Singularity = HPC-friendly container

Runs as Non-Root → Secure for shared HPC environments.

Native Scheduler Hooks → Accurate resource tracking & fair-share scheduling.

Direct Host Filesystem Access → No overlay penalty; ideal for PDKs & scratch.

Inherits Host Limits → /dev/shm and ulimits work out-of-the-box.

Seamless HPC Features → MPI, GPUs, Infiniband supported natively.

Preserves Host Identity → Stable for floating license servers.

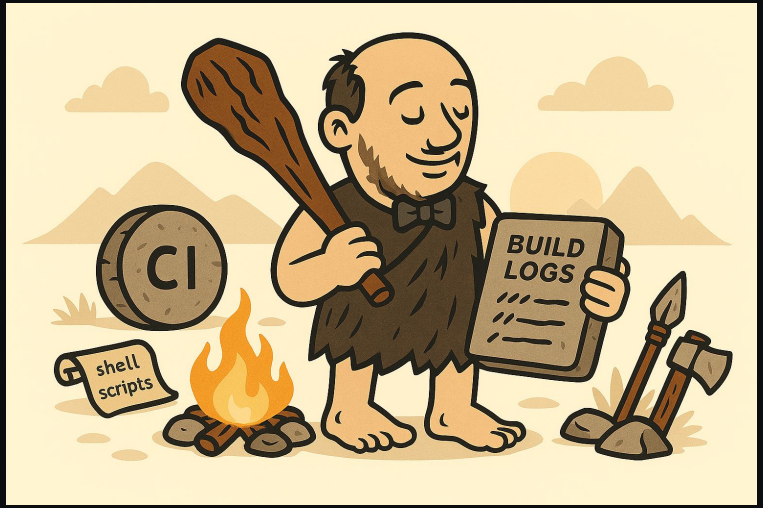
Life Before Airflow

“Before there was automation, before there was orchestration…
there was chaos.
And before there was chaos… there was Jenkins.”

Life Before Airflow - Jenkins

The Bad:

- Unstable Executor Nodes: Frequent failures (resource, network, software, grid) → cascading regressions failures & delays.
- Fragile Infrastructure: Node failures require manual recovery; high maintenance overhead.
- Siloed Freestyle Workflows: Hard to share or generalize methodologies across teams.
- No Version Control for Jobs: Configurations live only on Jenkins host → risk of loss, no audit trail.
- Poor Scalability for Complex Pipelines: Designed for simple CI/CD; struggles with large distributed workflows.



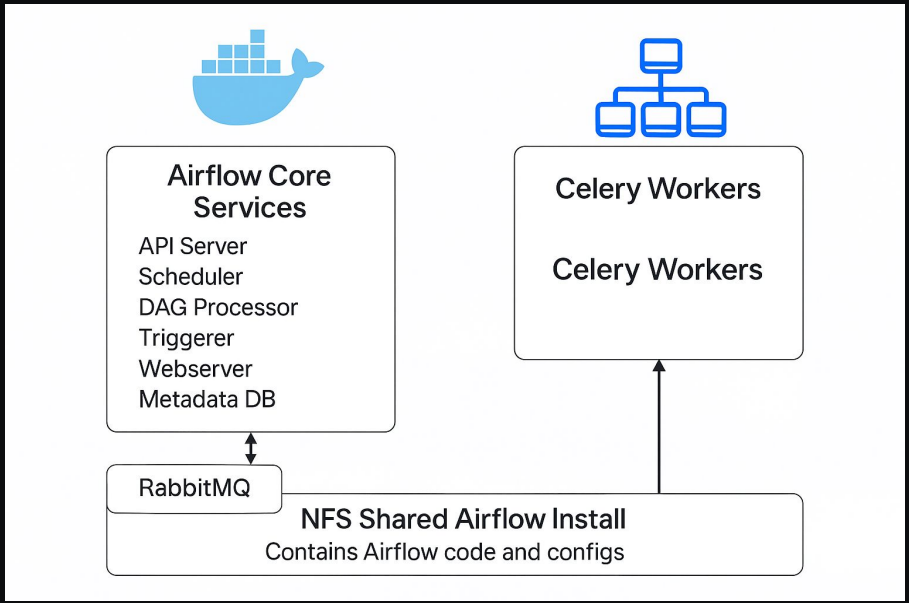
Life Before Airflow - Jenkins

The Good:

Airflow @ QCOM

Our Airflow Instance:

- Core services run in Docker container
- Airflow install/code/configs shared via NFS
- Celery workers run as LSF jobs



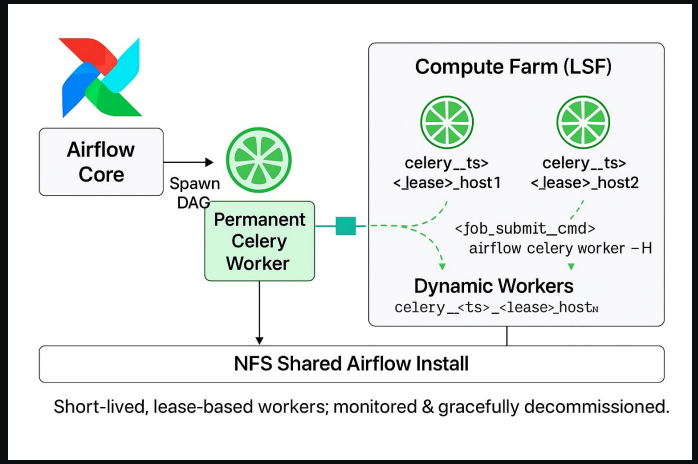
Dynamic Celery Workers

Spawning Celery Workers:

- Single always-on worker leases temporary workers on multi-day lease
- Temp workers created/shutdown via DAG:

```
job --cpus 8 --mem 64GB --  airflow celery worker -H
celery_<timestamp>_<lease_hrs>_<hostname>
```

- We contributed this for remote celery worker management!



Add CLI command to remove all queues from Celery worker ✓ area:providers provider:celery
#56195 by dheerajturaga was merged yesterday • Approved

Enhance Celery CLI with Worker and Queue Management Features ✓ area:providers provider:celery
#51257 by dheerajturaga was merged on Jun 1 • Approved

Add worker_umask to celery provider.yaml ✓ area:providers provider:celery
#51218 by dheerajturaga was merged on Jun 1 • Approved

```
Usage: airflow celery [-h] COMMAND ...

Start celery components. Works only when using CeleryExecutor. For more informa
tion, see https://airflow.apache.org/docs/apache-airflow/stable/executor/celery
.html

Positional Arguments:
  COMMAND
    add-queue           Subscribe Celery worker to specified queues
    flower              Start a Celery Flower
    list-workers        List active celery workers
    remove-queue        Unsubscribe Celery worker from specified queues
    shutdown-all-workers
                        Request graceful shutdown of all active celery workers
    shutdown-worker     Request graceful shutdown of celery workers
    stop                Stop the Celery worker gracefully
    worker              Start a Celery worker node
```

How do we scale up from here???

Challenges:

- Data Center is FULL -> Need more compute
- Compute availability is spread across many DCs
- Need to access Emulation resources
- Need to run on hosts hooked up to custom silicon

Can a single Airflow instance handle EVERYTHING?

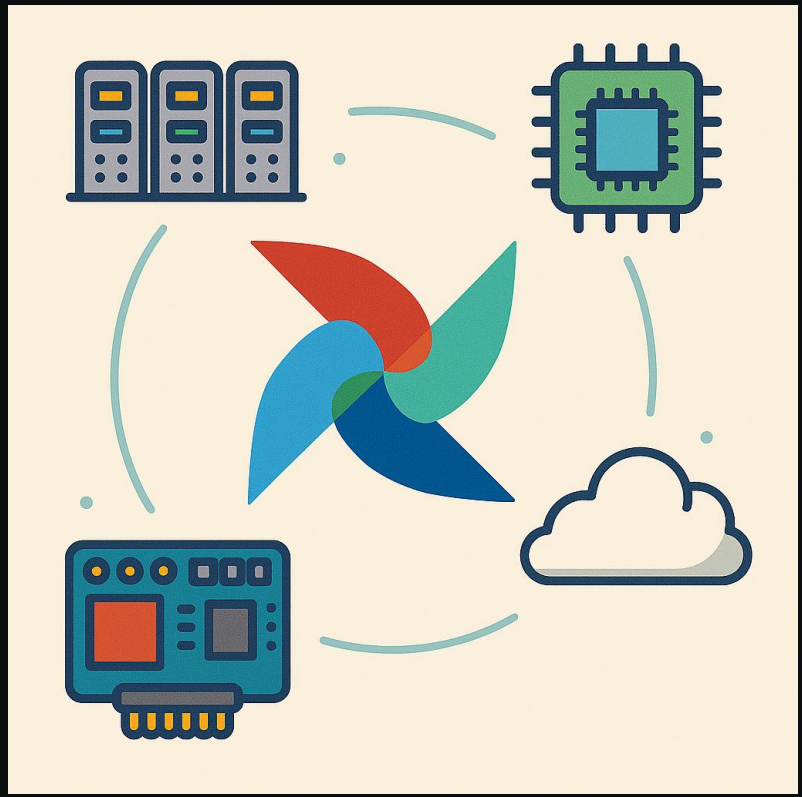
Multi Executors: Celery + Edge3

Celery → Local jobs in the same data center
Edge → Remote jobs & special hardware, anywhere!

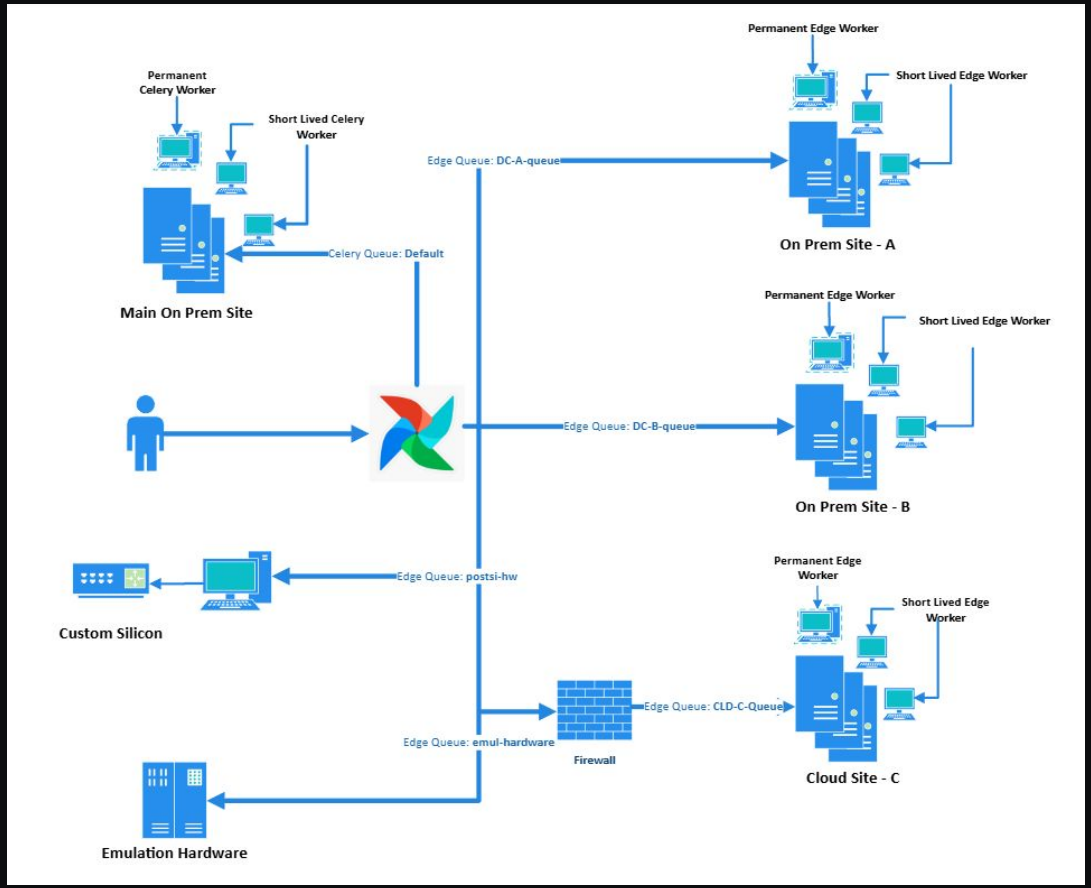
Why it rocks:
✅ One Airflow to rule them all
✅ Global compute orchestration
✅ No more DC handcuffs

How we do it:
- Permanent Edge Workers in each DC (always-on gateways)
- Dynamic Edge Workers spin up on demand
- Smart Routing: Celery for local, Edge for remote
- Load Balancing across DCs

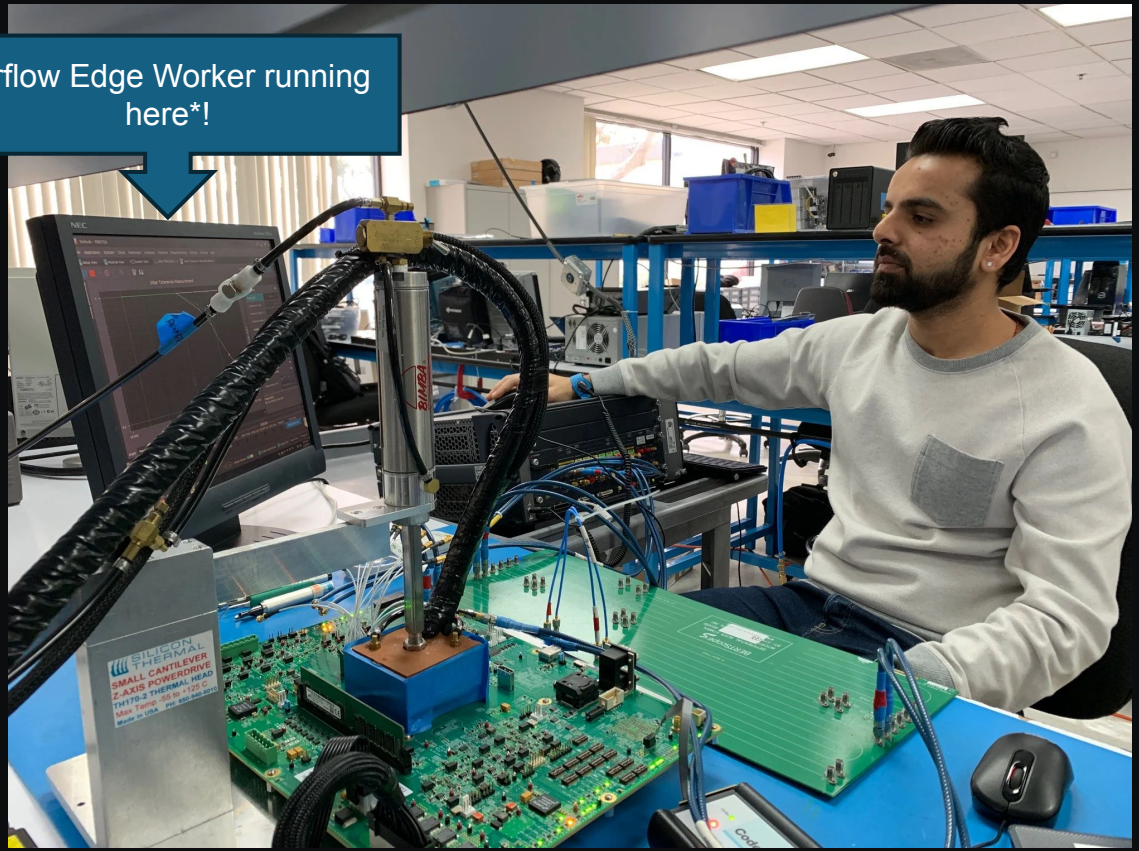
Use Cases:
Pre-Silicon: Build on HPC, run on emulators
Post-Silicon: Validate on custom boards



Airflow @ QCOM – Multi-DC Architecture



Airflow @ QCOM – Custom Sillicon



*This is a representative image only.

Edge/Celery Contributions

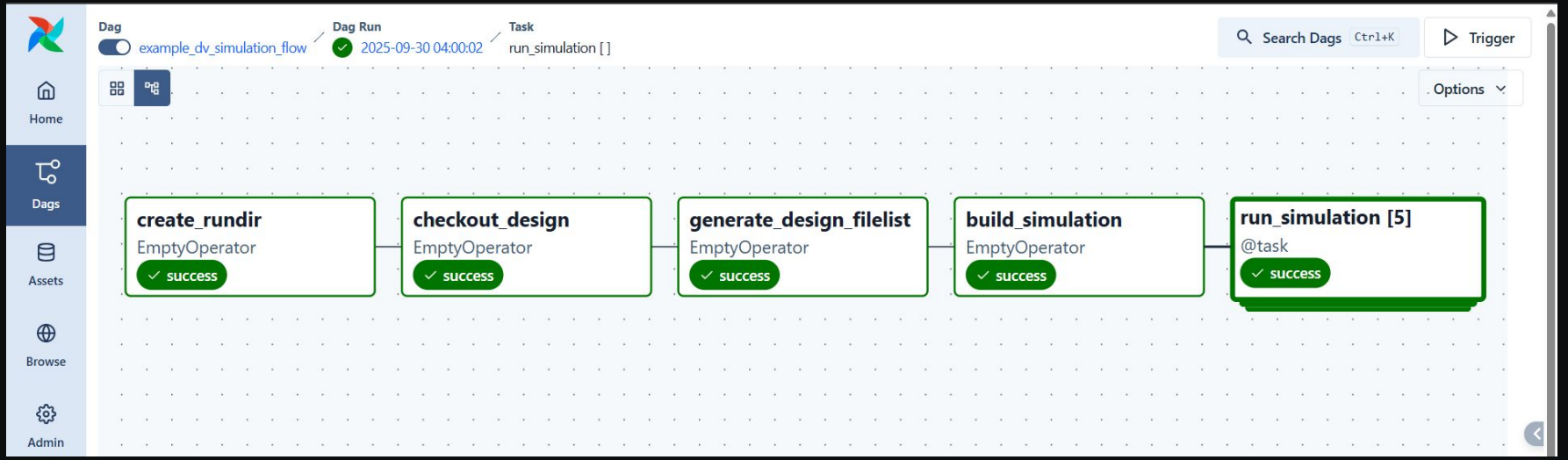
- Add revoke_task implementation to EdgeExecutor for task queued timeout support ✓ area:providers provider:edge
  #56240 by dheerajturaga was merged 3 days ago • Approved
- Add CLI command to remove all queues from Celery worker ✓ area:providers provider:celery
  #56195 by dheerajturaga was merged 3 days ago • Approved
- Add yellow hover background to enter maintenance icon ✓ area:providers provider:edge
  #55631 by dheerajturaga was merged 3 weeks ago • Approved
- Add shutdown-all-workers command to Edge CLI ✓ area:providers provider:edge
  #55626 by dheerajturaga was merged 3 weeks ago • Approved
- Add queue management UI buttons for Edge workers ✓ area:providers provider:edge
  #55625 by dheerajturaga was merged 3 weeks ago • Approved
- feat: Add delete button for offline edge workers ✓ area:providers provider:edge
  #55529 by dheerajturaga was merged 3 weeks ago • Approved
- feat: Add shutdown button for edge workers with confirmation dialog ✓ area:providers provider:edge
  #55513 by dheerajturaga was merged 3 weeks ago • Approved
- Add confirmation dialog for exit maintenance action in Edge Worker Page ✓ area:providers provider:edge
  #55400 by dheerajturaga was merged 3 weeks ago • Approved
- Add worker maintenance mode functionality to Edge3 provider UI ✓ area:providers provider:edge
  #55301 by dheerajturaga was merged last month • Approved
- Fix EdgeWorker multiprocessing pickle error on Windows ✓ area:providers provider:edge
  #55284 by dheerajturaga was merged last month • Approved
- Add queue and remove queue cli commands for EdgeExecutor ✓ area:providers provider:edge
  #53505 by dheerajturaga was merged on Jul 19 • Approved
- Edge list worker cli command to list active job metrics ✓ area:providers provider:edge
  #51720 by dheerajturaga was merged on Jun 14 • Approved
- Extend command column in the edge_job table to accomodate more chars ✓ area:providers provider:edge
  #51716 by dheerajturaga was merged on Jun 14 • Approved
- Enhance Celery CLI with Worker and Queue Management Features ✓ area:providers provider:celery
  #51257 by dheerajturaga was merged on Jun 1 • Approved
- Add worker_umask to celery provider.yaml ✓ area:providers provider:celery
  #51218 by dheerajturaga was merged on Jun 1 • Approved
- Support For Edge Worker in Daemon Mode ✓ area:providers provider:edge
  #50425 by dheerajturaga was merged on May 11 • Approved
- Ability to request shutdown of a remote edge worker ✓ area:providers provider:edge
  #50278 by dheerajturaga was merged on May 6 • Approved
- Extend Edge Worker CLI commands operate on remote edge workers ✓ area:providers provider:edge
  #49915 by dheerajturaga was merged on May 2 • Approved
- Minor doc fix in edge_executor ✓ area:providers kind:documentation provider:edge
  #49755 by dheerajturaga was merged on Apr 25 • Approved

View all our contributions here:

Methodologies

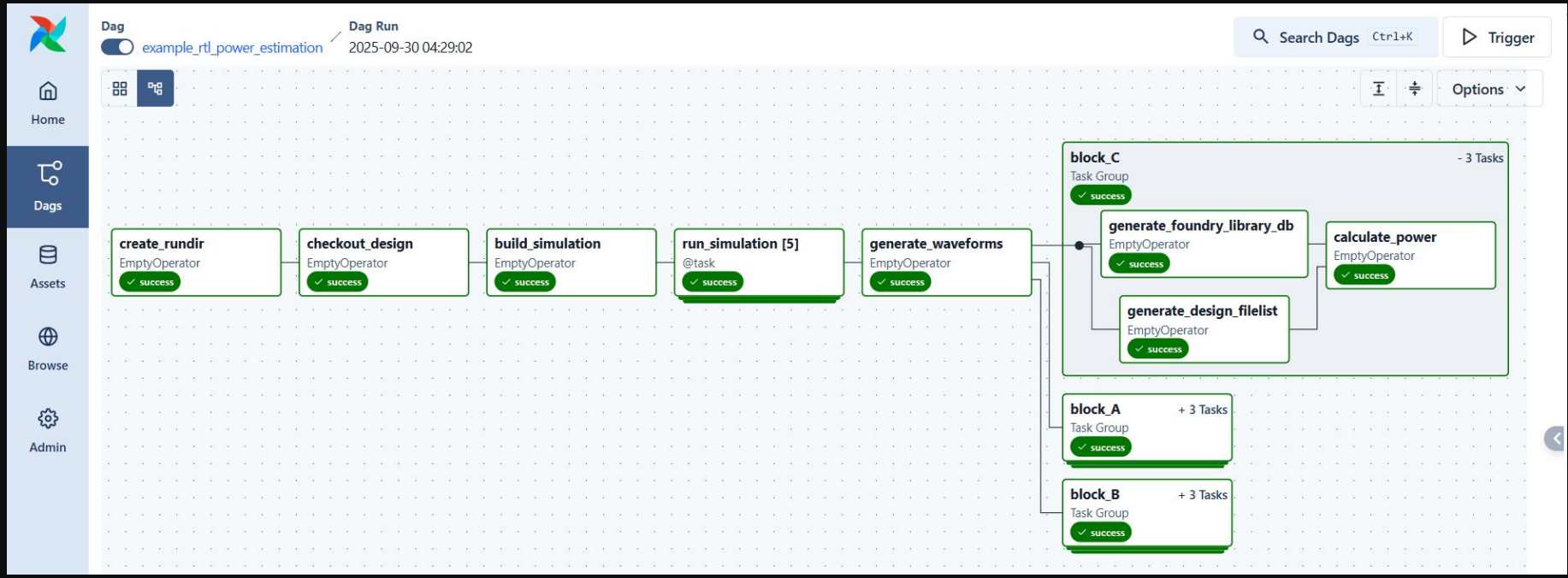
Chip Design Workflow – Examples (DV)

Design Verification (DV) is debugging hardware before it's built — to catch costly mistakes early.



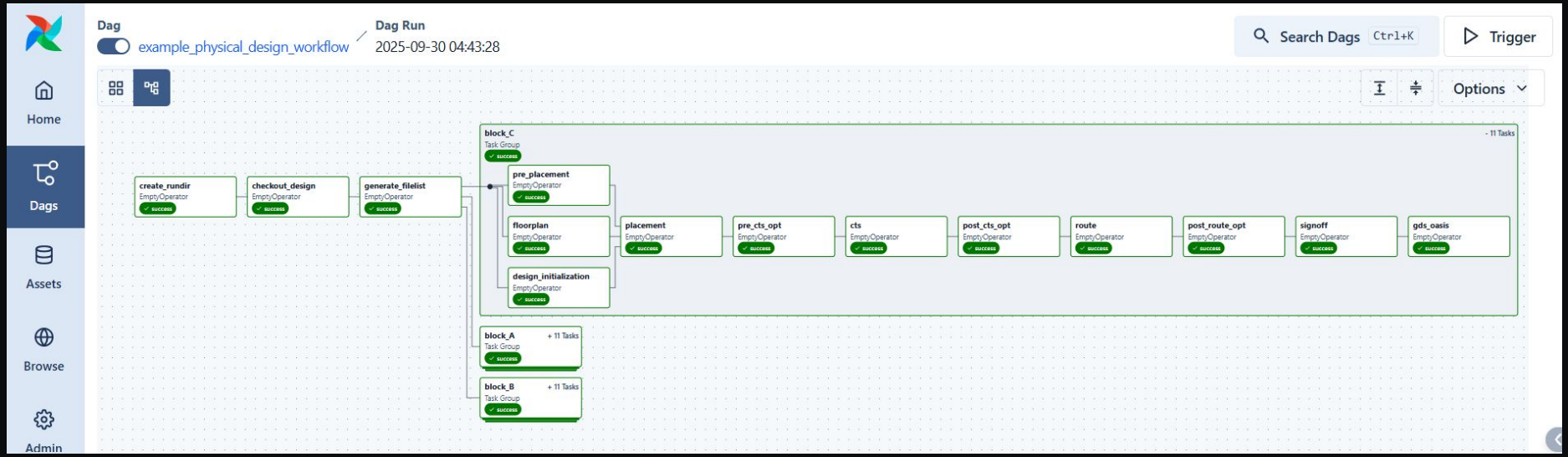
Chip Design Workflow – Examples (Power Estimation)

RTL power estimation is simulating the chip's power efficiency using its design plans before fabrication.



Chip Design Workflow – Examples (Physical Design)

Physical Design is the process of converting a chip's logical design into a layout that can be manufactured on silicon..



Pytest Plugin for Airflow

Unit testing an Airflow codebase:

- ‘airflow dags list-import errors’ is not enough!
- No official Pytest support ☹️
- Custom Pytest plugin -> apache-airflow-devel-common -> pytest_plugin.py source code

```python
@pytest.mark.db_test
@pytest.mark.smoke
@pytest.mark.execution_timeout(3000)
def test_integrity(dags_path):
    """
    Replaces `airflow dags list-import-errors`
    """
    dag_bag = DagBag(
        dag_folder=dags_path, include_examples=False, read_dags_from_db=False
    )
    assert not dag_bag.import_errors, "DAG import errors are present :("
    slowpokes = [
        s for s in dag_bag.dagbag_stats if s.duration > duration(seconds=10)
    ]
    assert not slowpokes, "Slowpokes are present :("
```

Pytest Plugin for Airflow

```python
@pytest.mark.db_test
@pytest.mark.execution_timeout(300)
def test_a_dag(dag_maker, session, default_args):
    """
    Test a DAG!
    """
    DAG_CFG = {
        # something relevant
    }
    with dag_maker(
        dag_id="test_a_dag",
        bundle_name="dags-folder",
        default_args=default_args,
        params=BASE_PARAMS(DAG_CFG),
        session=session,
    ):
        ...
    dr = dag_maker.create_dagrun(run_type=DagRunType.MANUAL)
    for ti in dr.get_task_instances(
        session=session
    ):  # Mimic the specific order the scheduling would run the tests.
        ti.run(session=session)
        assert ti.state == TaskInstanceState.SUCCESS, f"{ti} failed!"
    dr.update_state(session=session)
    assert dr.state == DagRunState.SUCCESS, f"{dr} failed!"
    # more asserts
```

```python
class TestCustomOperator:

    @pytest.mark.db_test
    def test_templated_fields(self, create_task_instance_of_operator, session):
        ti = create_task_instance_of_operator(
            CustomOperator,
            # Templated fields
            bash_command='echo "{{ dag_run.dag_id }}"',
            env={"FOO": "{{ ds }}"},
            cwd="{{ task.dag.folder }}",
            # Other parameters
            dag_id="test_templated_fields_dag",
            task_id="test_templated_fields_task",
            session=session,
        )
        context = ti.get_template_context(session=session)
        ti.render_templates(context=context)
        task: CustomOperator = ti.task
        assert task.bash_command.endswith('echo "test_templated_fields_dag"')
        assert task.cwd == Path(__file__).absolute().parent.as_posix()
```

Custom Shell Operators

Shell Operators:

- Source global shell .rc file
- Modify SubprocessHook to pass entire stdout/output log path
- Custom pre/post-processing via pre_execute/post_execute
- Enables smart retries + scraping XComs from shell output

```python
class SubprocessHook(BaseHook):  <- class CustomHook(SubprocessHook)
    ...
    def run_command(
        self,
        command: list[str],
        env: dict[str, str] | None = None,
        output_encoding: str = "utf-8",
        cwd: str | None = None,  <- Add optional output_log
    ) -> SubprocessResult:
        """
```

```python
class BashOperator(BaseOperator):  <- class CustomOperator(BashOperator)
    ...  <- def execute() uses CustomHook
    def __init__(
        self,
        *,
        bash_command: str | ArgNotSet,  <- Prepend env setup commands
        env: dict[str, str] | None = None,
        append_env: bool = False,
        output_encoding: str = "utf-8",
        skip_on_exit_code: int | Container[int]
        cwd: str | None = None,
        **kwargs,
    ) -> None:
```

DAG Templates

Generalizing Workflows:

- DAG Factories but very different!
- Use symlinks to DAG templates + YAML dictionary configuration
- Enforce methodology with a unit test!
- .airflowignore:
  - **/templates/
  - **/*_template.py

```
my_dag/
├─ cfg.yml
├─ dag.py  ->  templates/dag_template.py
└─ templates/
   └─ dag_template.py
```

```python
@pytest.mark.db_test
@pytest.mark.smoke
def test_symlink_methodology(dags_path):
    """
    Enforce my rules!
    """

    for p in dags_path.rglob("*"):
        if p.is_symlink():
            # check if broken link
            # check for adjacent cfg.yml
```

Questions?

Dheeraj Turaga
turaga@qti.qualcomm.com

Nick Redd
redd@qti.qualcomm.com

Like what we do?

COME JOIN US!
WE ARE HIRING

Airflow

Infrastructure &
Automation Engineer –
Silicon Design

Apply Here!

Qualcomm
Snapdragon