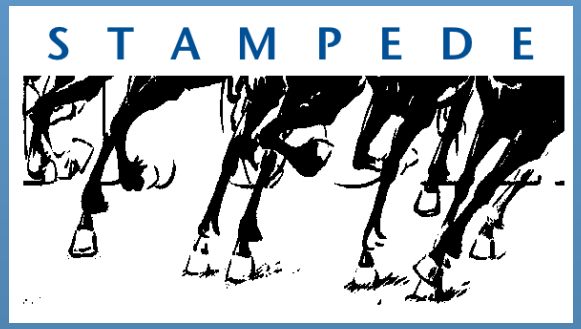



# A General Approach to Real-time Workflow Monitoring

*Karan Vahi , Ewa Deelman, Gaurang Mehta, Fabio Silva*

*USC Information Sciences Institute*

*Ian Harvey, Ian Taylor, Kieran Evans, Dave Rogers, Andrew Jones, Eddie El-Shakarchi*

*School of Computer Science, Cardiff University*

*Taghrid Samak, Dan Gunter, Monte Goode*

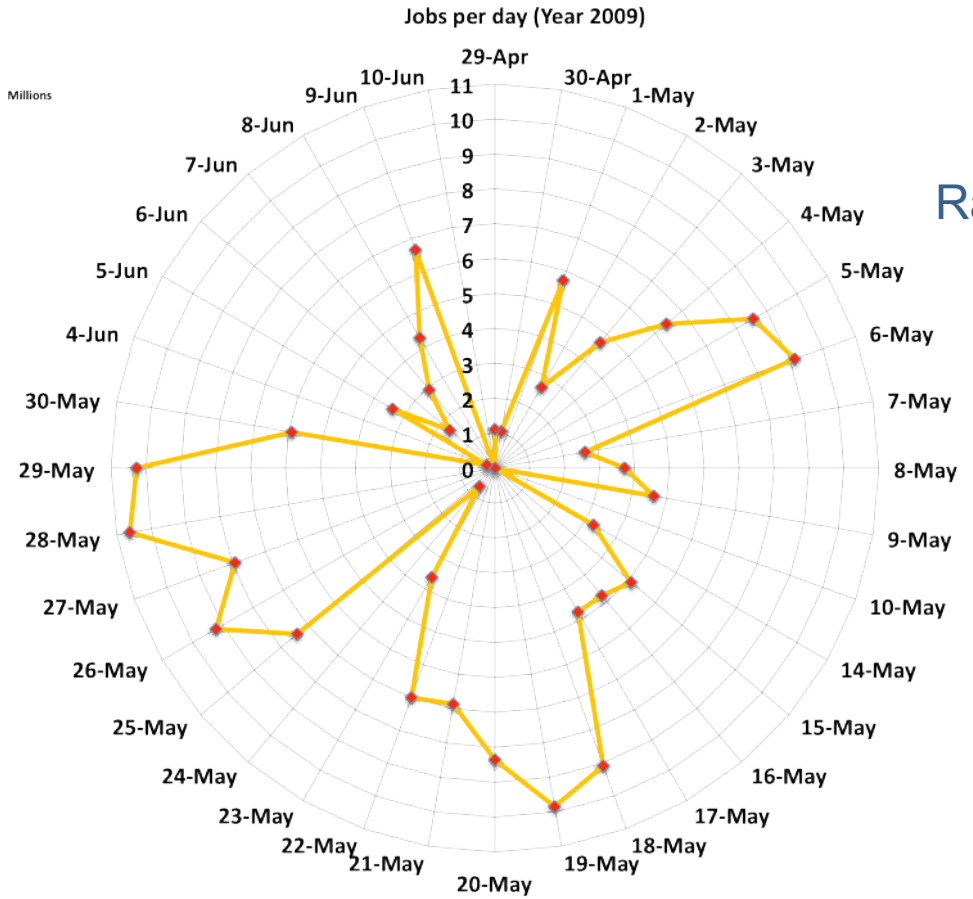
*Lawrence Berkeley National Laboratory*

# Outline

- Background
- Stampede Data Model
- Triana and Stampede Integration
- Experiments and Analysis Tools
- Conclusions and Future Work

# Domain: Large Scientific Workflows

## SCEC-2009: Millions of tasks completed per day




Radius = 11 million

# Goal: Real-time Monitoring and Analysis

1. Monitor Workflows in real time
   - Scientific workflows can involve many sub-workflows and millions of individual tasks
   - Need to correlate across workflow and job logs
   - Provide realtime updates on the workflow – how many jobs completed, failed etc
2. Troubleshoot Workflows
   - Provide users with tools to debug workflows, and provide information of why a job failed
3. Visualize Workflow performance
   - Provide a workflow monitoring dashboard that shows the various workflows run
4. Provide Analysis tools
   - Is a given workflow going to "fail"?
   - Are specific resources causing problems?
   - Which application sub-components are failing?
   - Is the data staging a problem?
5. **Do all of this as generally as possible: Can we provide a solution that can apply to all workflow systems?**

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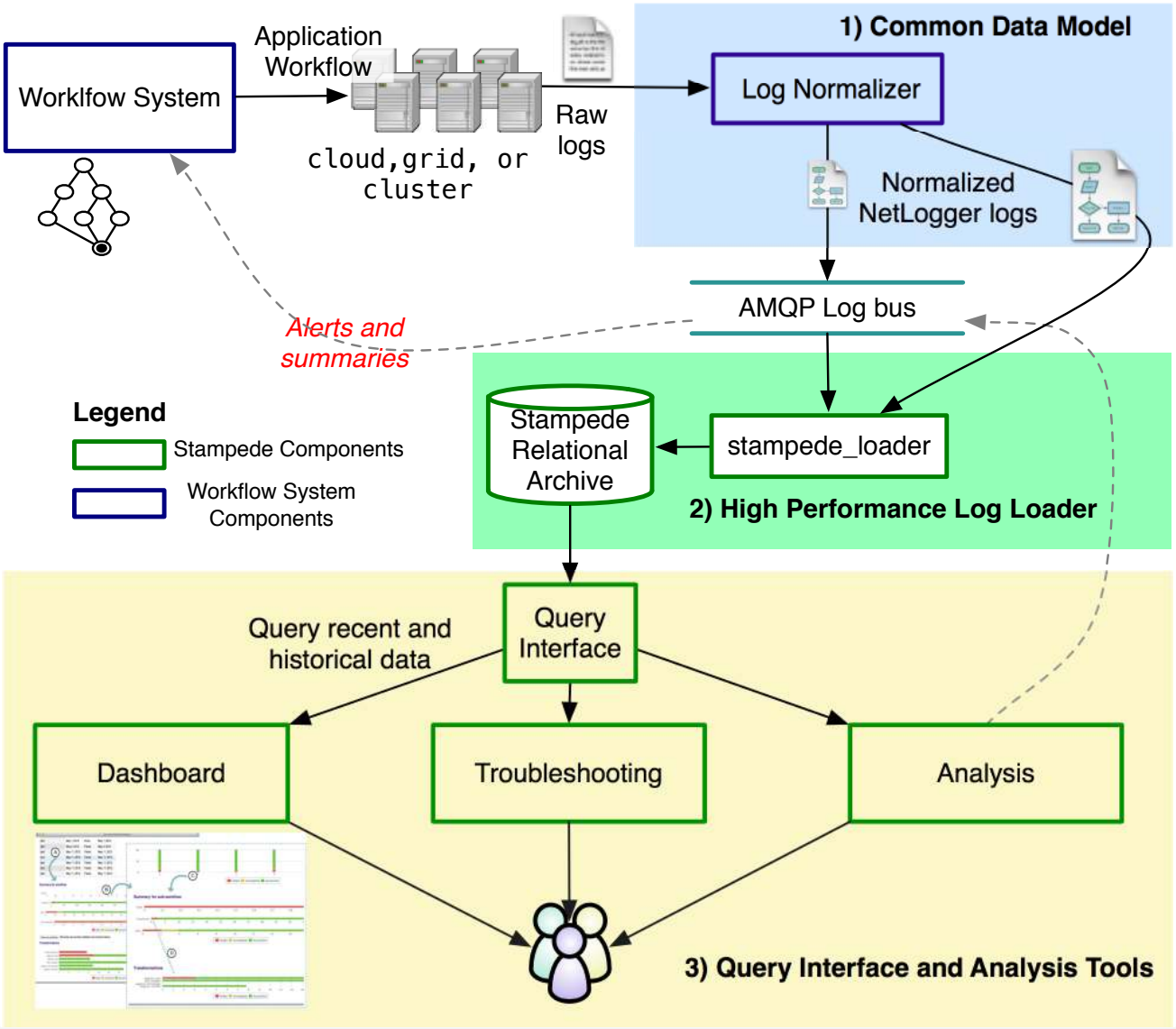
# How Does Stampede Provide Interoperability



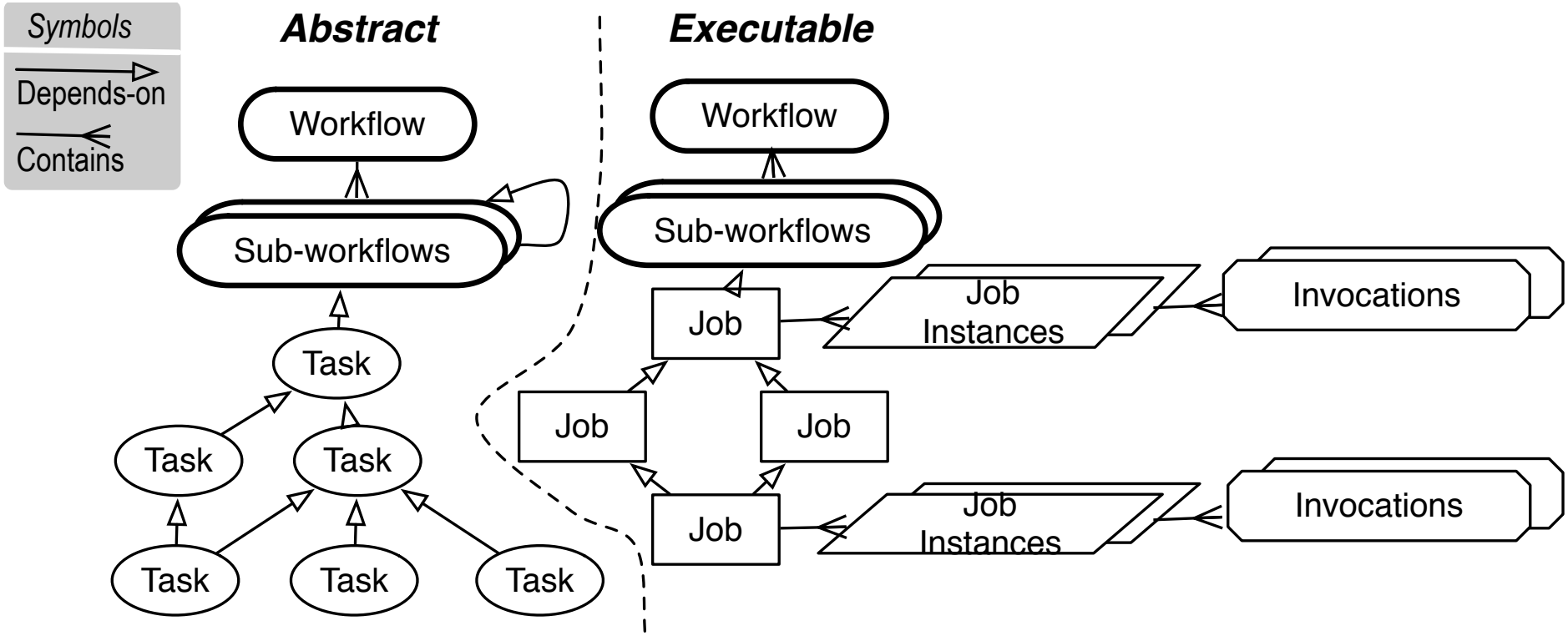
# Abstract and Executable Workflows

- Workflows start as a resource-independent statement of computations, input and output data, and dependencies
  - This is called the Abstract Workflow (AW)
- For each workflow run, workflow systems may plan the workflow, adding helper tasks and clustering small computations together
  - This is called the Executable Workflow (EW)
- Note: Most of the logs are from the EW but the user really only knows the AW. The model allows us to connect jobs in the user specified (AW) with the jobs in EW executed through Workflow Systems

# Entities in Stampede Data Model

- **Workflow**: Container for an entire computation
- **Sub-workflow**: Workflow that is contained in another workflow
- **Task**: Representation of a computation in the AW
- **Job**: Node in the EW
  - May represent one or more tasks in the AW. Or can represent jobs added by Workflow System (e.g., a stage-in/out),
- **Job instance**: Job scheduled or running by underlying system
  - Due to retries, there may be multiple job instances per job
- **Invocation**: captures actual invocation of an executable on
  - When a job instance is executed on a node, one or more invocations can be associated. The invocations capture the runtime execution of tasks specified in the AW

# Relationship between Entities in Stampede Data Model



# Logs Normalization

- Logging Methodology
  - Workflow Systems generate logs in the netlogger format
    - Timestamped, named, messages at the *start* and *end* of significant events, with additional *identifiers* and metadata in a std. line-oriented ASCII format (Best Practices or BP)
    - APIs are provided

Example Log Message

```
ts=2012-03-13T12:35:38.000000Z event=stampede.xwf.start
level=Info xwf.id=ea17e8ac-02ac-4909-b5e3-16e367392556
restart_count=0
```

- Yang schema to describe the events in netlogger format
  - YANG schema documents and validates each log event

http://acs.lbl.gov/projects/stampede/4.0/stampede-schema.html

Snippet of schema

```
container stampede.xwf.start {
  description “Start of executable workflow”;
  uses base-event;
  leaf restart_count {
    type uint32;
    description  "Number of times workflow was restarted (due to
failures)”; }}
```

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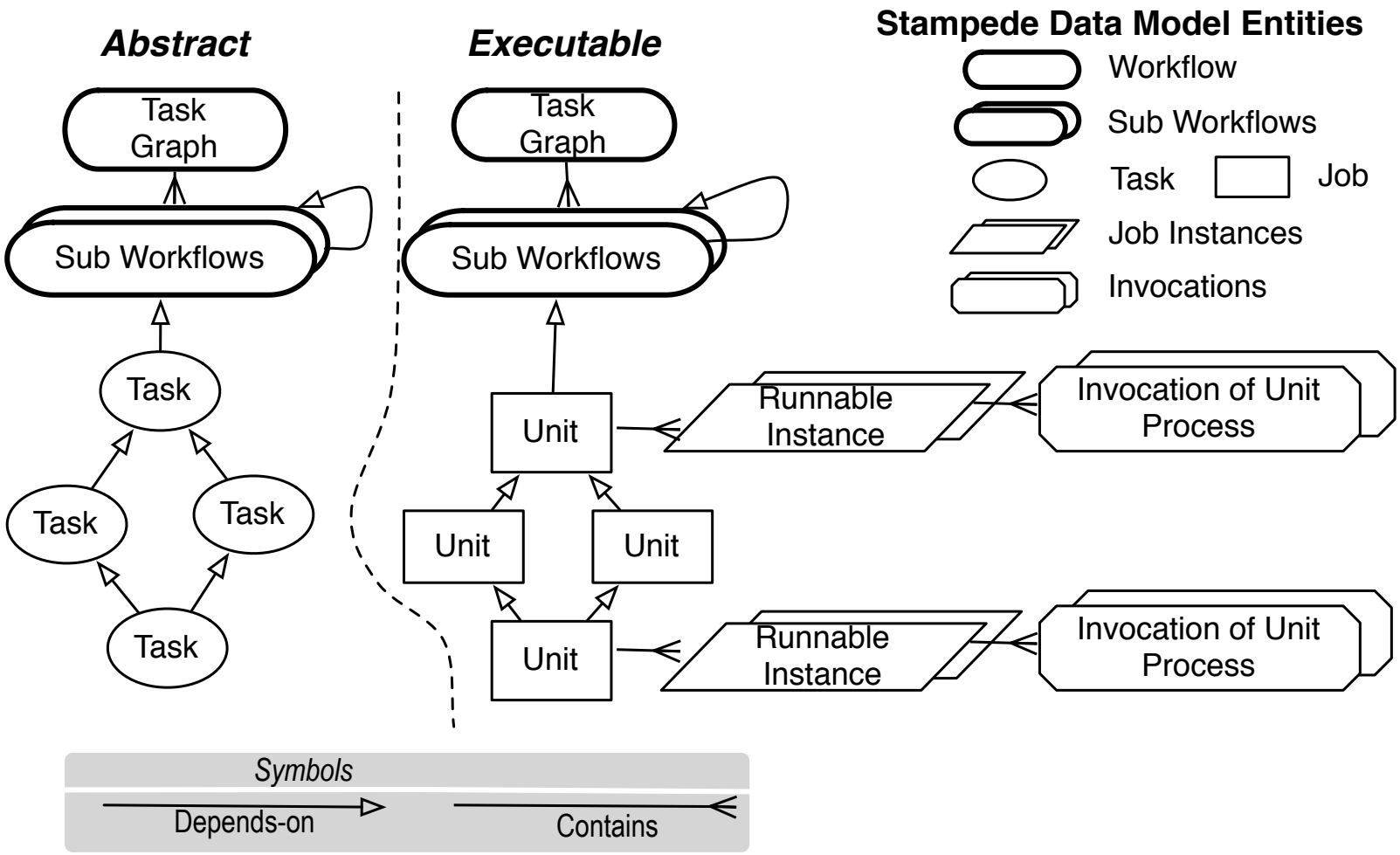
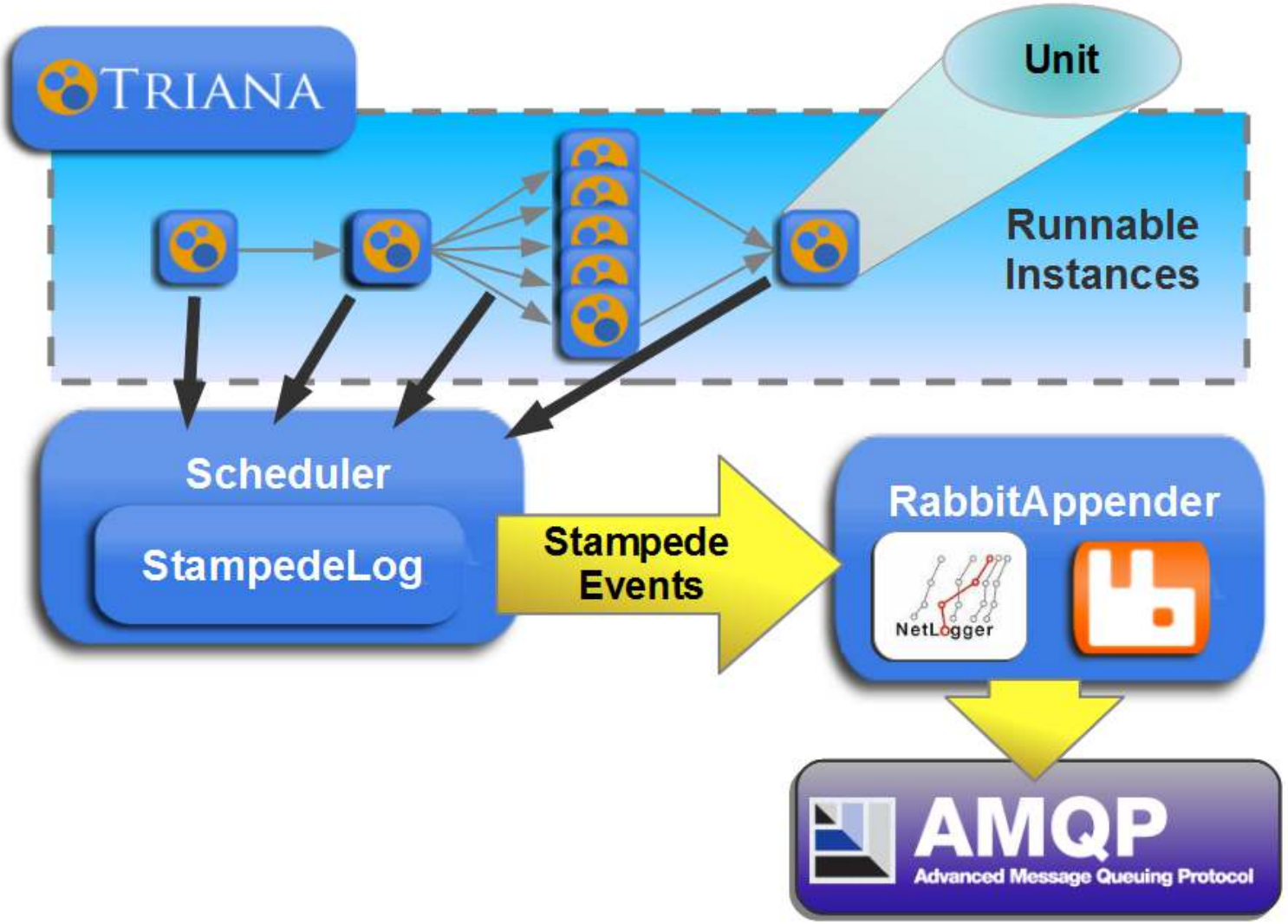
## Triana Workflow System

- Workflow and Data Analysis Environment
- Interactive GUI to enable workflow composition
- Focused on data flows of Java components
- Has a wide range palette of tools that can be used to design applications
- Can distribute workloads to remote Cloud VM's

# Mapping With Stampede Data Model



# Triana Integration With Stampede



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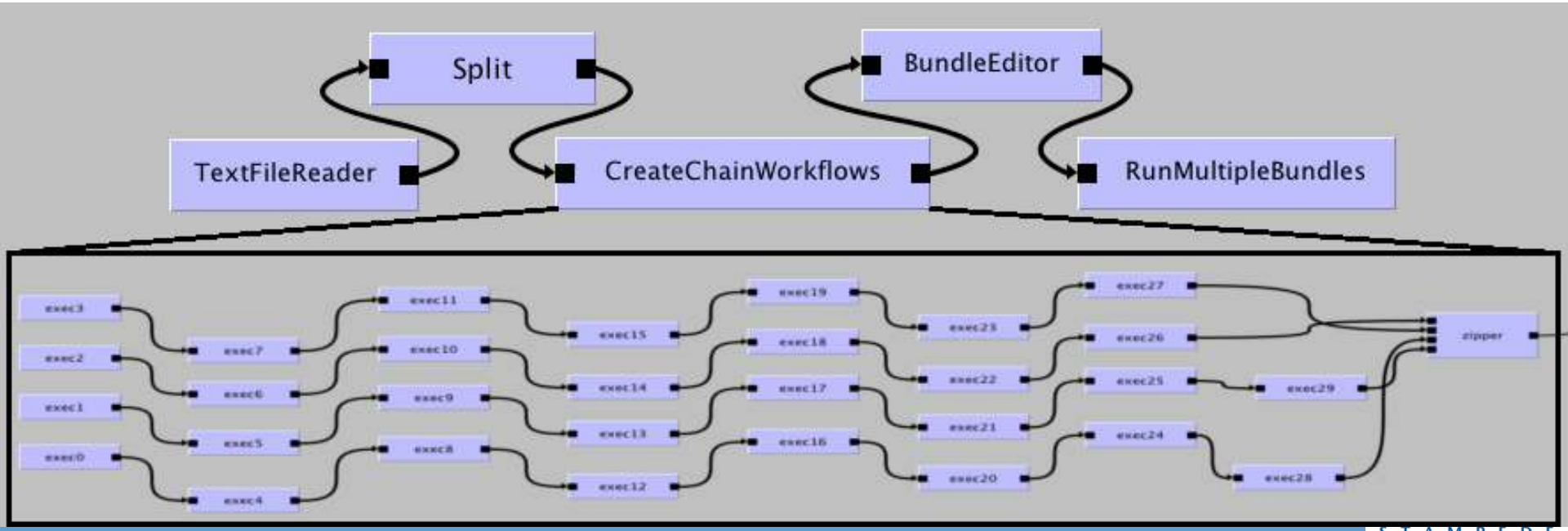
## Scientific Experiment

- DART Audio Processing Workflow
  - DART algorithm is portable and package as a jar file.
  - Parameter sweep resulting in 306 DART application invocations
  - Executed on a Triana Cloud Deployment in Cardiff



# Performance Statistics - *stampede-statistics*

## Workflow Statistics

| Type | Succeeded | Failed | Incomplete | Total | Ret-ries | Total |
|---|---|---|---|---|---|---|
| Tasks | 367 | 0 | 0 | 367 | 0 | 367 |
| Jobs | 367 | 0 | 0 | 367 | 0 | 367 |
| Sub WF | 20 | 0 | 0 | 20 | 0 | 20 |

Workflow wall time : 11 mins, 1 sec, ( 661 seconds).
Workflow cumulative job wall time : 11 hrs, 10 mins, (40224 seconds).

TABLE I
SUMMARY OUTPUT FROM STAMPEDE-STATISTICS FOR DART WORKFLOW

## TASK Statistics Per Sub Workflow

| Type | Count | Success | Failed | Min | Max | Mean | Total |
|---|---|---|---|---|---|---|---|
| 115-119 | 1 | 1 | 0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Output_0 | 1 | 1 | 0 | 1.0 | 1.0 | 1.0 | 1.0 |
| exec0 | 1 | 1 | 0 | 74.0 | 74.0 | 74.0 | 74.0 |
| exec1 | 1 | 1 | 0 | 75.0 | 75.0 | 75.0 | 75.0 |
| exec2 | 1 | 1 | 0 | 74.0 | 74.0 | 74.0 | 74.0 |
| exec3 | 1 | 1 | 0 | 75.0 | 75.0 | 75.0 | 75.0 |
| exec4 | 1 | 1 | 0 | 36.0 | 36.0 | 36.0 | 36.0 |
| zipper | 1 | 1 | 0 | 1.0 | 1.0 | 1.0 | 1.0 |

TABLE II
BREAKDOWN.TXT DESCRIBING THE TASKS IN A SUB-WORKFLOW

# Performance Statistics - *stampede-statistics*

| Job | Try | Site | Invocation Duration |
|---|---|---|---|
| unit:304-305 | 1 | trianaworker6 | 1.0 |
| exec1 | 1 | trianaworker6 | 64.0 |
| file.Output_0 | 1 | trianaworker6 | 1.0 |
| file.zipper | 1 | trianaworker6 | 1.0 |
| processing.exec0 | 1 | trianaworker6 | 51.0 |

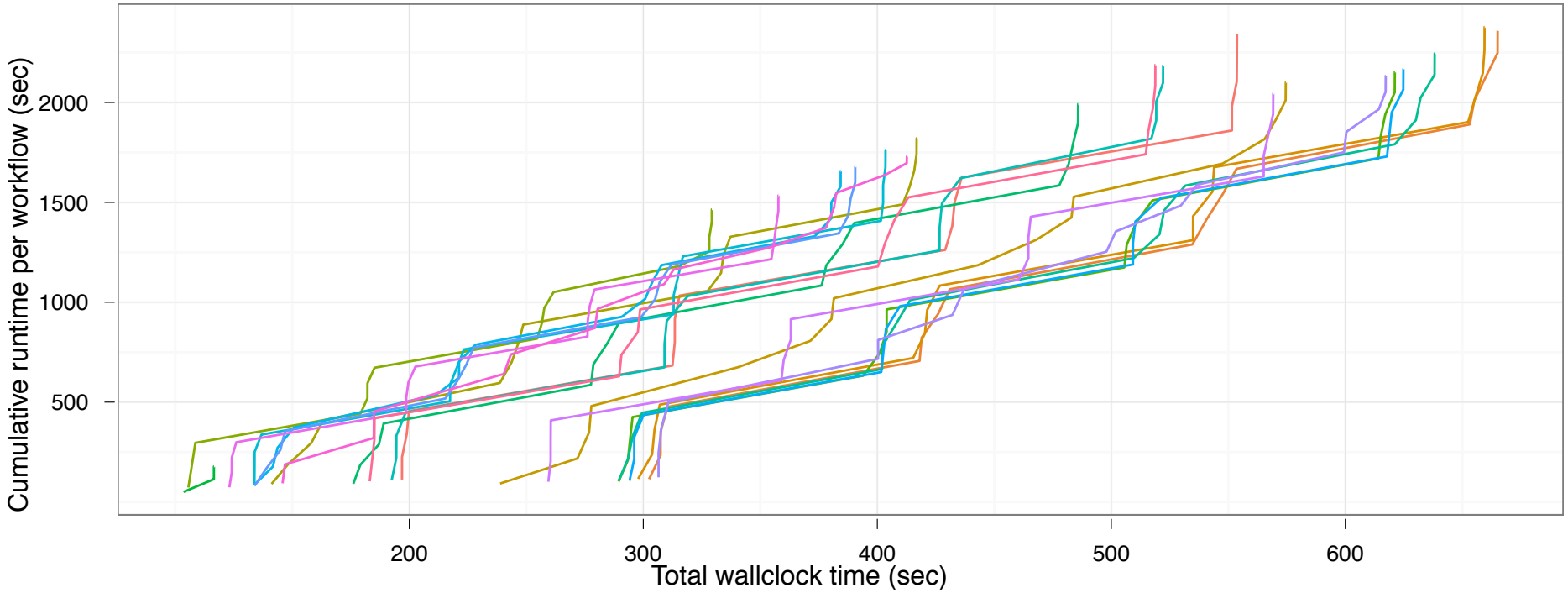
TABLE III
SECTION OF JOBS.TXT FOR A SINGLE SUB WORKFLOW

## Job Level Statistics

| Job | Queue Time | Runtime | Exit | Host |
|---|---|---|---|---|
| unit:304-305 | 0.06 | 1.0 | 0 | None |
| exec1 | 0.04 | 64.0 | 0 | trianaworker6 |
| file.Output_0 | 0.0 | 1.0 | 0 | trianaworker6 |
| file.zipper | 0.0 | 1.0 | 0 | trianaworker6 |
| processing.exec0 | 0.07 | 51.0 | 0 | trianaworker6 |

TABLE IV
SECTION OF JOBS.TXT FOR A SINGLE SUB WORKFLOW

# Workflow Analysis using R



# Troubleshooting and Dashboard

## Stampede-analyzer

- Interactive debugging tool
- Identifies what jobs failed and why they failed
- Drill down functionality for hierarchal workflows

## Stampede Dashboard – Available Soon

- Lightweight Performance Dashboard
- Online monitoring and status of workflows
- Troubleshoot failed jobs
- Charts and statistics online

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# Conclusions and Future Work

- Real-time failure prediction for scientific workflows is a challenging and important task
- Stampede provides a 3 layer model for integration with different workflow systems
  - Has been integrated with Pegasus WMS and now with Triana
  - Provides users useful real-time monitoring , debugging and analysis tools
- Apply Workflow and Job Failure prediction models to Triana Runs
- Dashboard for easier visualization of collected data

# Thank you!



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