



INDIANA UNIVERSITY  
**SCHOOL OF INFORMATICS,  
COMPUTING, AND ENGINEERING**

## **Project Stages and Intro to Airavata**

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# Todays Outline

- Project Steps
- Science Gateways Introduction
- Apache Airavata high level overview
- Open Discussion

# Course Communication

- For syllabus information and presentation material, see the course website
  - <http://courses.airavata.org>
- For project assignments and other communications, use Canvas

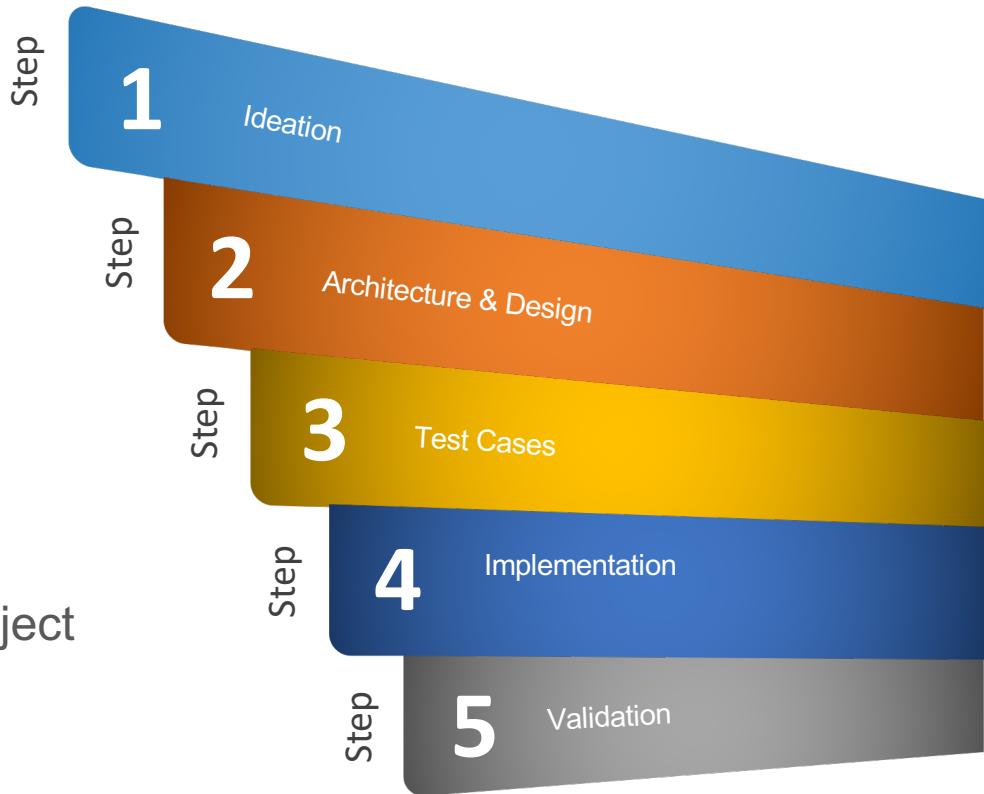
# Project Life Cycle

Break your project into:

# 5

## Graded Steps

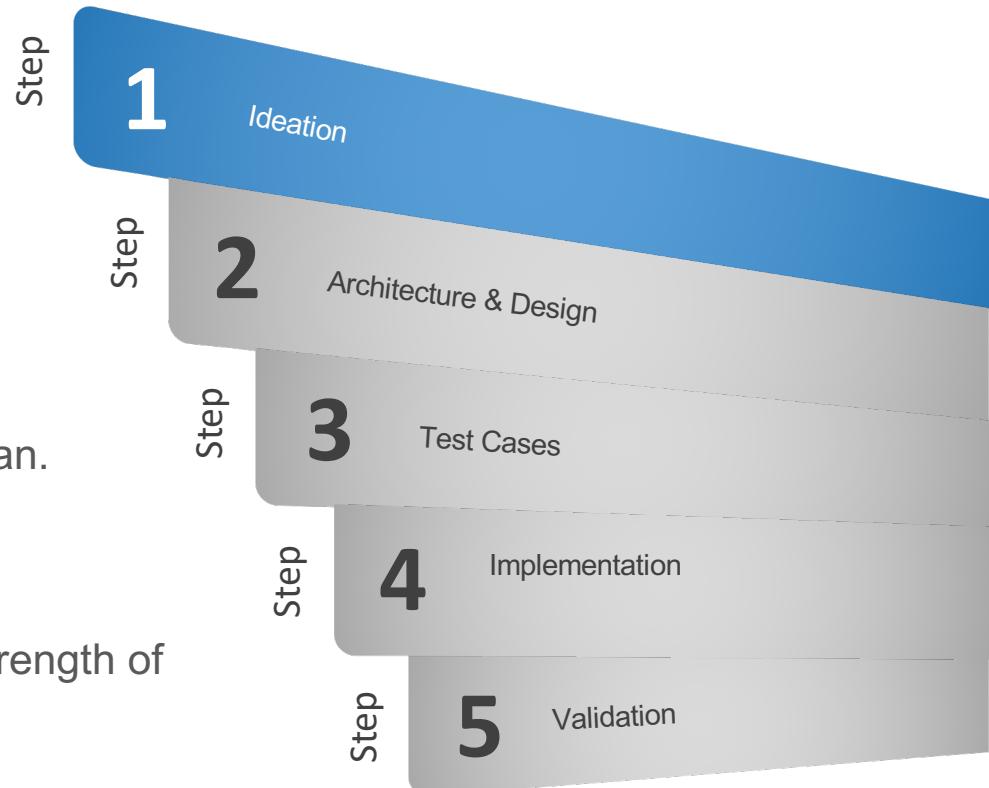
All these artifacts need to be in your project repository and will be peer-reviewed



# Project Idea

## 01

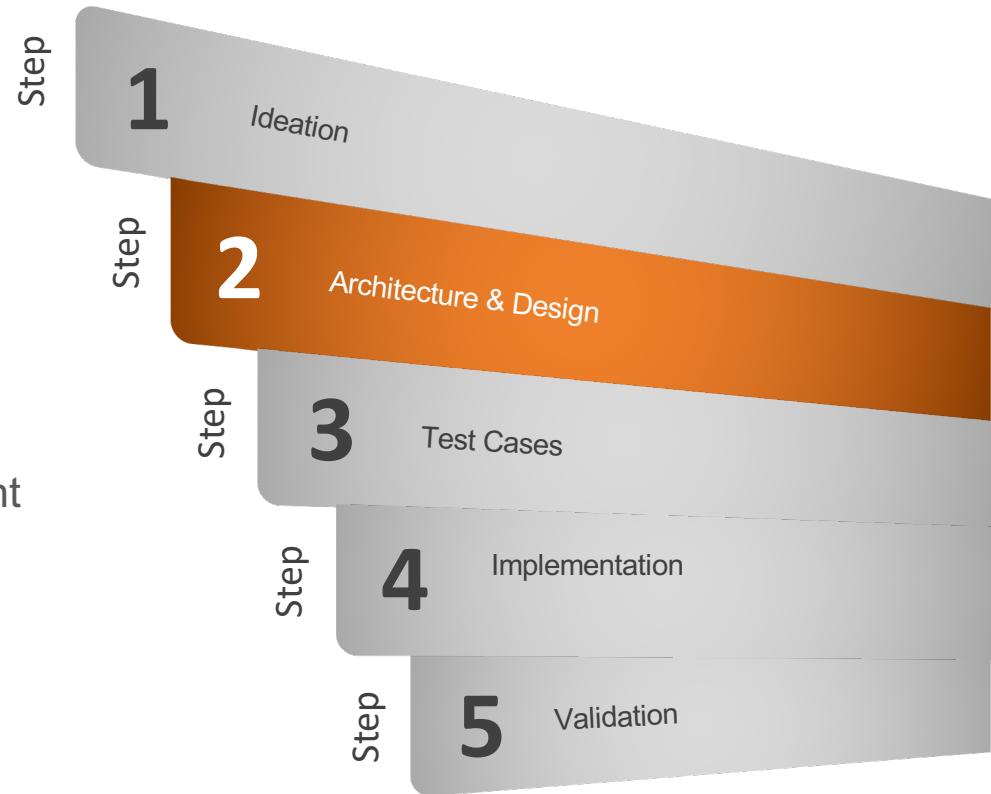
- Articulate your idea as a user story.
  - Describe as many variations as you can.
  - Do not yet describe how the system accomplishes them.
- Draw a napkin drawing of your idea.
- Articulate the value proposition (central strength of your project).



# White Board Architecting

## 02

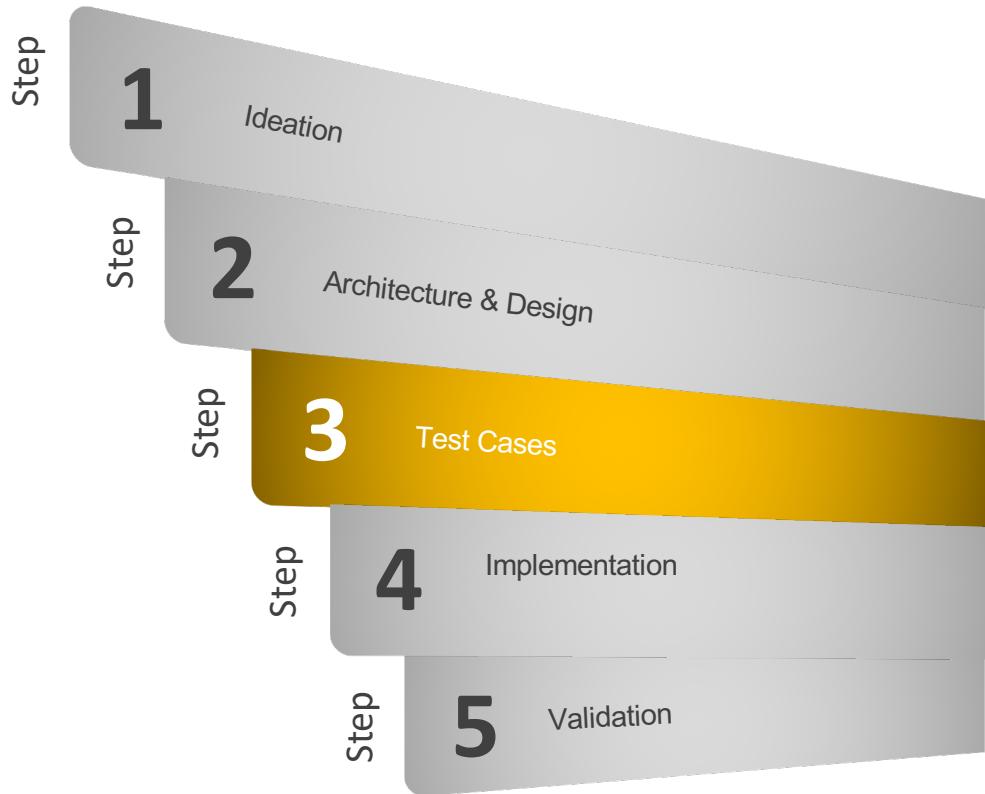
- Draw an architecture on how you will accomplish the project.
- Do not yet discuss how you will implement it.
- Identify the basic components needed.
- Leave out the implementation details.
- Identify the components which are your unique contributions (value propositions).



# Test Cases – Usage Scenarios

# 03

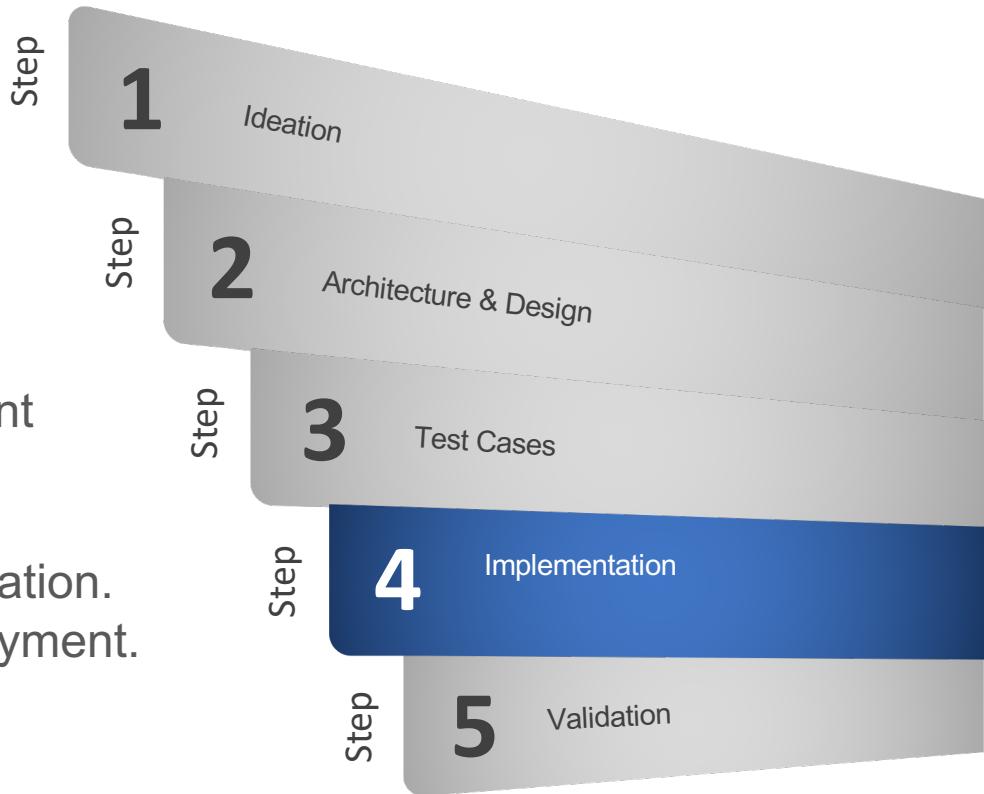
- Write usage scenarios as test cases
- Think about programmability of the test cases



# Implement the Architecture

## 04

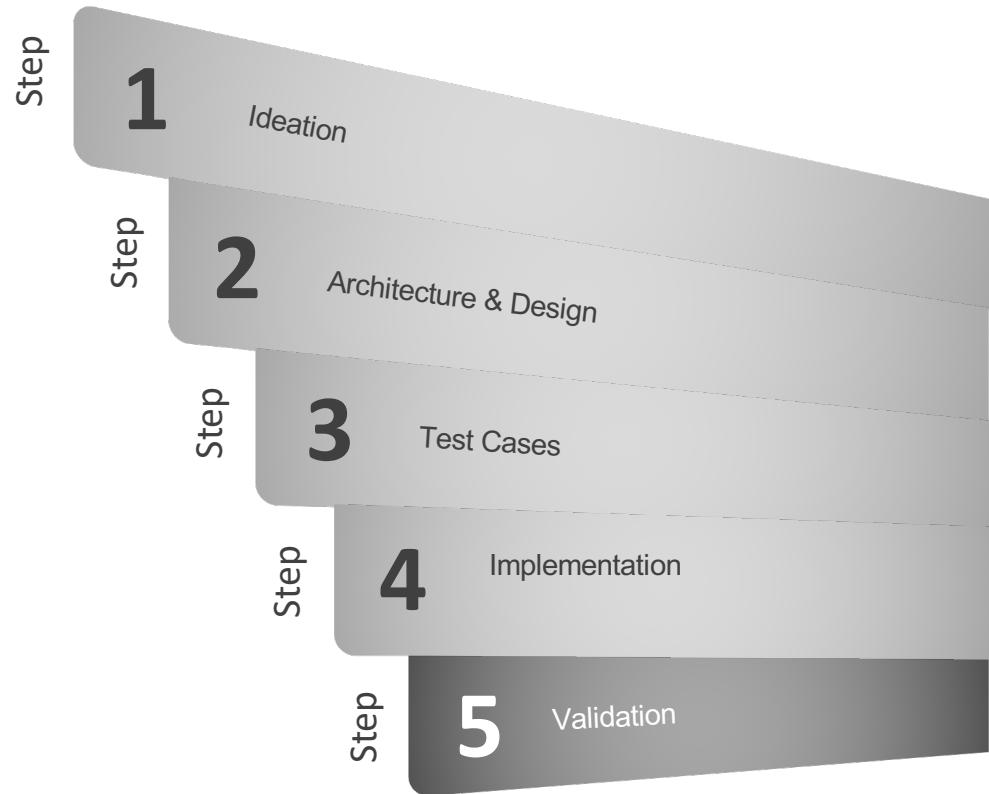
- Implement the architecture in 3 different programming languages.
- Use a build system.
- Configure Travis-CI Continuous Integration.
- Use Ansible to have a one-click Deployment.



# Validate the system

# 05

- Run through test cases
- Peer-reviewers will need to identify more testing scenarios.
- Rinse and Repeat

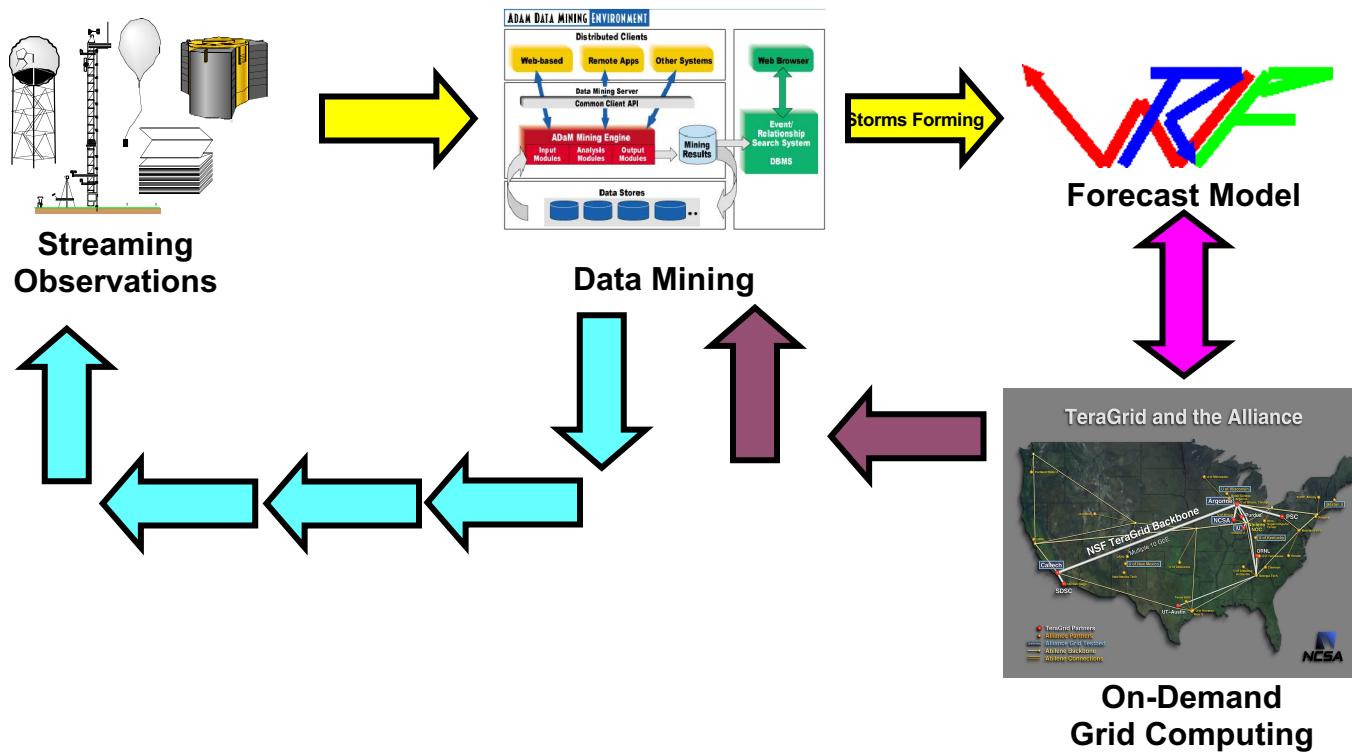




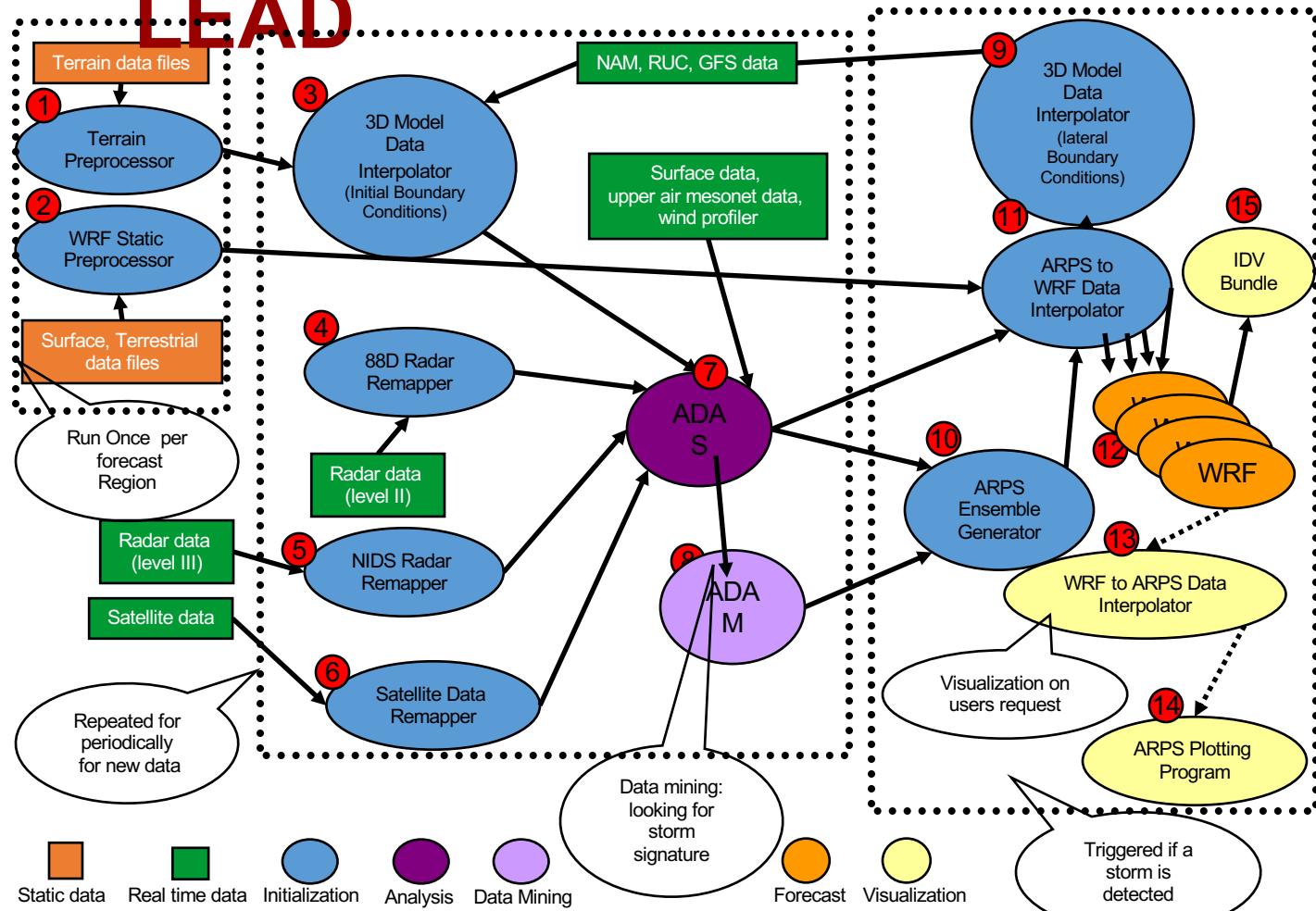
LINKED  
ENVIRONMENTS  
FOR ATMOSPHERIC  
DISCOVERY



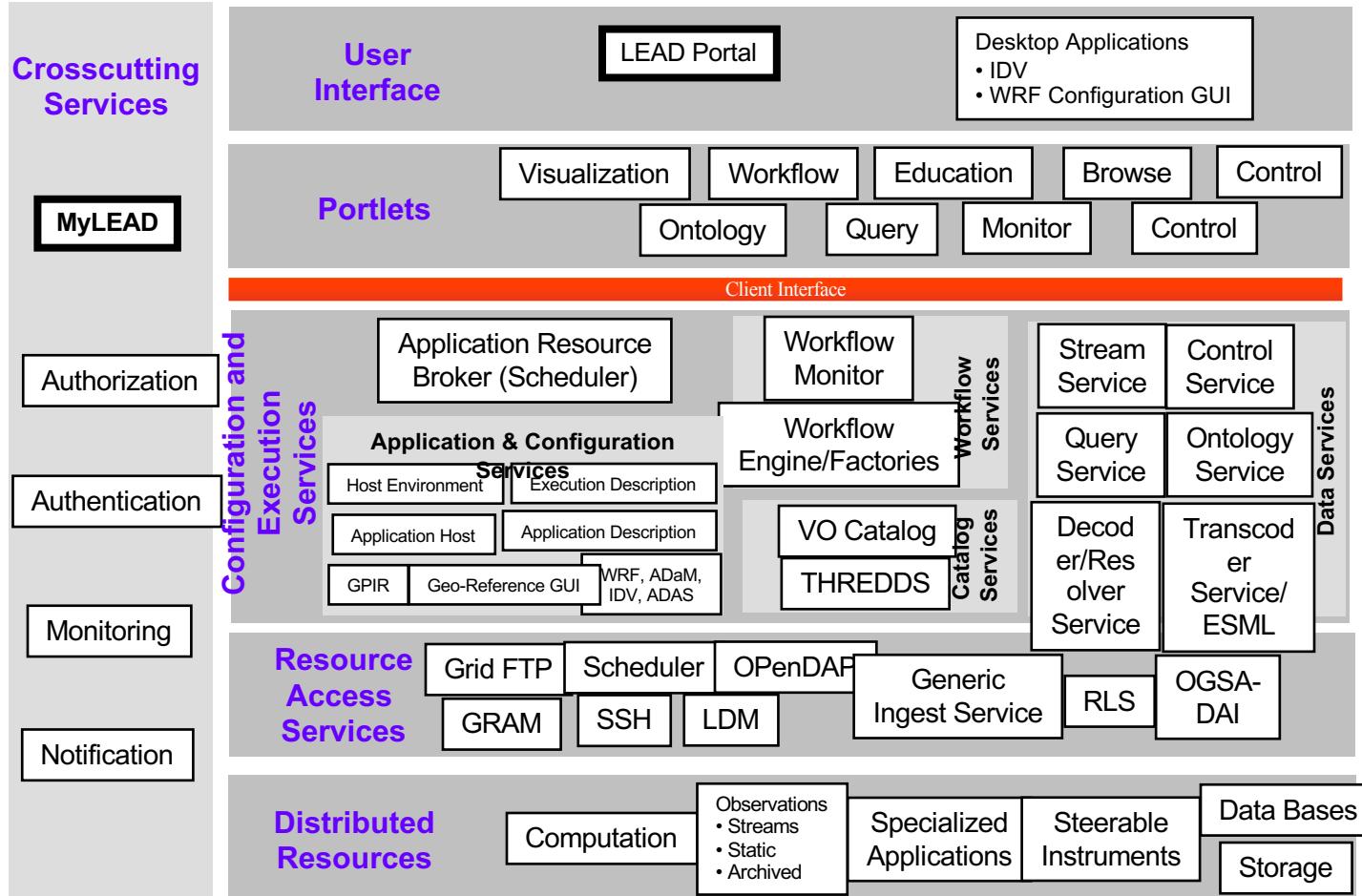
# Adapting Weather Prediction to Observational Sources Using Dynamic Adaptivity



# Dynamic Workflow In LEAD



# LEAD Architecture





LEADPORTAL  
LINKED ENVIRONMENTS FOR ATMOSPHERIC DISCOVERY

SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION

NSF

HOME MY WORKSPACE ABOUT LEAD DATA SEARCH RESOURCES HELP

Welcome

# Analyze & Predict

## WELCOME TO THE LEAD PORTAL

Linked Environments for Atmospheric Discovery (LEAD) makes meteorological data, forecast models, and analysis and visualization tools available to anyone who wants to interactively explore the atmosphere as it evolves. The LEAD Portal brings together all the necessary resources in one convenient access point ... [read more](#)

## FEATURES FOR ANYONE INTERESTED IN THE WEATHER

Discover & Visualize

## POPULAR TOOLS

Visualize Weather Data  
Integrated Data Viewer | MORE >

Create a Forecast or Analysis  
Experiment Builder | MORE >

Access Weather Data  
Geographic Region Search | MORE >

## QUICK LINKS

- Live Weather
- LEAD Grid
- LEAD Blog
- Glossary

- Frequently Asked Questions
- LEAD User Guide (password protected)

Research & Reproducibility

## THE LEAD TEAM



Colorado State University



HOWARD UNIVERSITY



INDIANA UNIVERSITY



MILLERSVILLE  
Find Your Future Here



UAH



UCAR



ILLINOIS



OKLAHOMA



UN

Education & Outreach

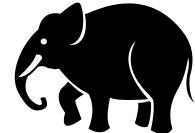
# Supercomputer?

# What is Supercomputing?

- *Supercomputing* is the **biggest, fastest computing right this minute.**
  - So, the definition of supercomputing is **constantly changing**.
  - GigaFLOPS, TeraFLOPS, PetaFLOPS, ExaFLOPS.....
- Supercomputing is also heard in context of :
  - *High Performance Computing (HPC)*,
  - *High End Computing (HEC)*,
  - Grid Computing
  - *Cyberinfrastructure (CI)*.

# What is Supercomputing About?

- **Size**: Many problems that are interesting to scientists and engineers **can't fit on a PC** – usually because they need more than a few GB of RAM, or more than a few 100 GB of disk.

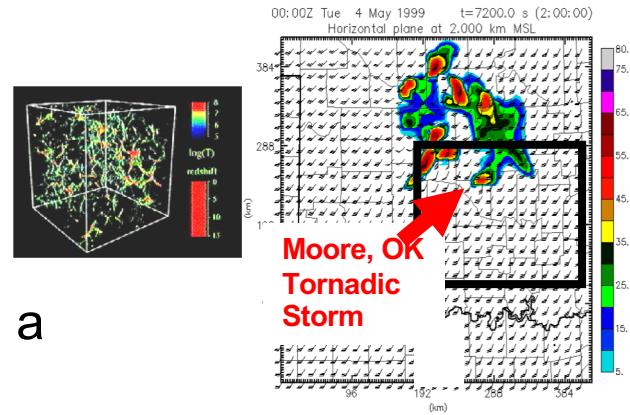


- **Speed**: Many problems that are interesting to scientists and engineers would take a very very long time to run on a PC: months or even years. But a problem that **would take a month on a PC** might take only **an hour on a supercomputer**.



# What is HPC Used For?

- Simulation of physical phenomena, such as
  - Weather forecasting
  - Galaxy formation
  - Oil reservoir management
- Data mining: finding needles of information in a haystack of data, such as
  - Gene sequencing
  - Signal processing
  - Detecting storms that might produce tornados
- Visualization: turning a vast sea of data into pictures that a scientist can understand

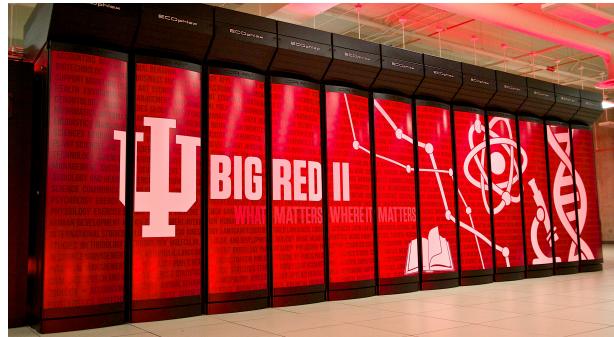


# What a Cluster is ....

A cluster is a collection of small computers, called nodes, hooked together by an interconnection network.

It also needs software that allows the nodes to communicate over the interconnect.

A cluster is ... is all of these components working together as if they're one big computer ... a super computer.



# What is Parallelism?

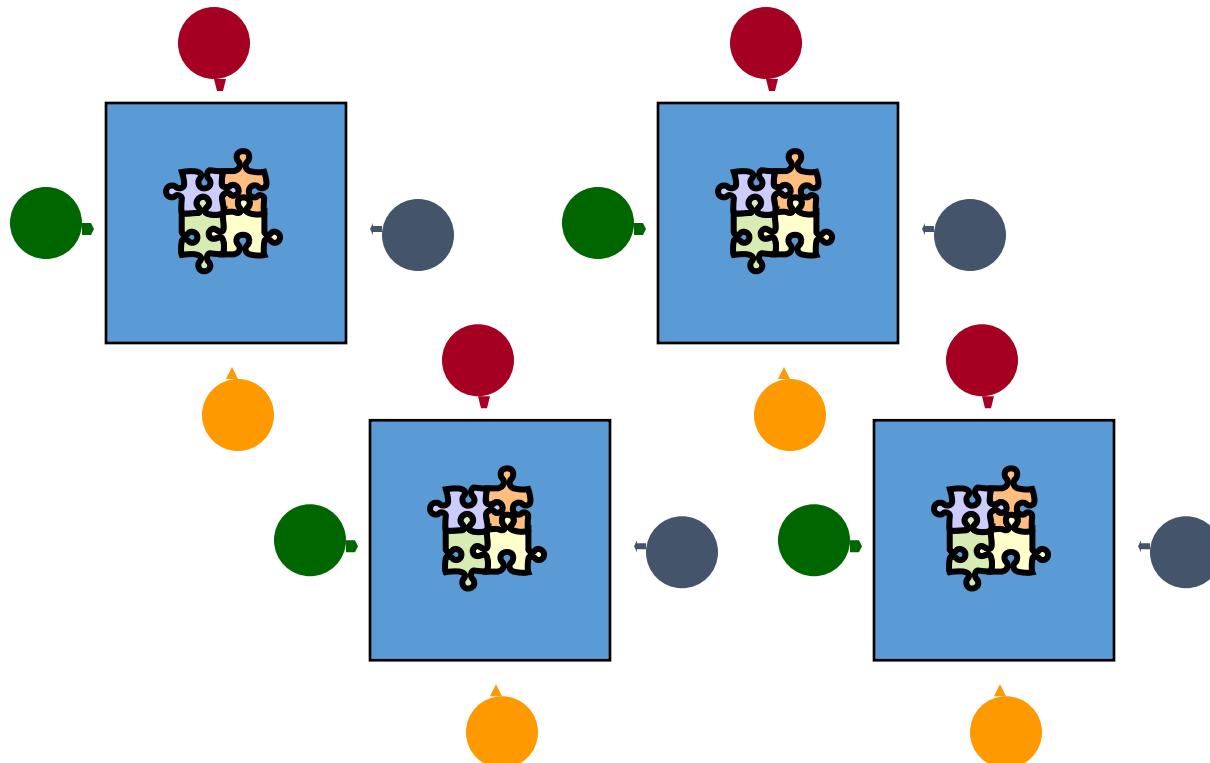
Parallelism is the use of multiple processing units – either processors or parts of an individual processor – to solve a problem, and in particular the use of multiple processing units operating concurrently on different parts of a problem.

The different parts could be different tasks, or the same task on different pieces of the problem's data.

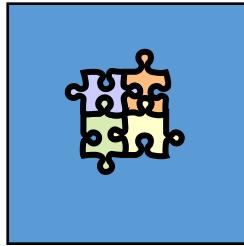
# Kinds of Parallelism

- Instruction Level Parallelism
- Shared Memory Multithreading
- Distributed Memory Multiprocessing
- GPU Parallelism
- Hybrid Parallelism (Shared + Distributed + GPU)

# The Jigsaw Puzzle Analogy

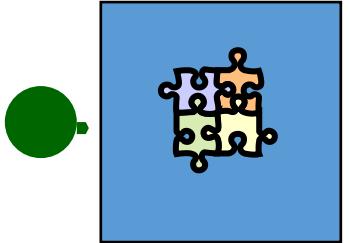


# Serial Computing



- Suppose you want to do a jigsaw puzzle that has, say, a thousand pieces.
- We can imagine that it'll take you a certain amount of time.
- Let's say that you can put the puzzle together in an hour.

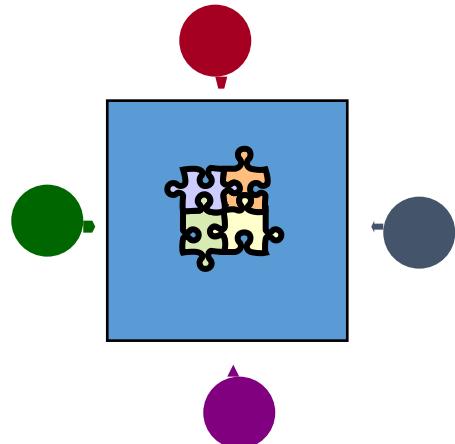
# Shared Memory Parallelism



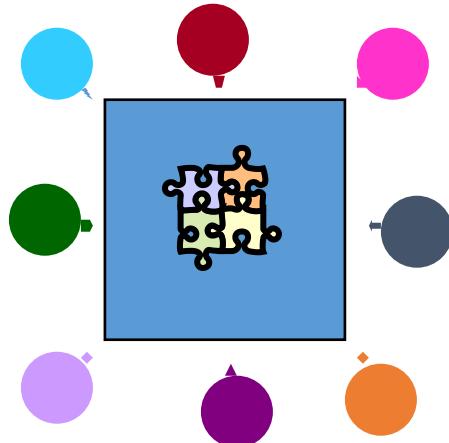
- If Scott sits across the table from you, then he can work on his half of the puzzle and you can work on yours.
- Once in a while, you'll both reach into the pile of pieces at the same time (you'll contend for the same resource), which will cause a little bit of slowdown.
- And from time to time you'll have to work together (communicate) at the interface between his half and yours.
- The speedup will be nearly 2-to-1: y'all might take 35 minutes instead of 30.

# The More the Merrier?

- Now let's put Paul and Charlie on the other two sides of the table.
- Each of you can work on a part of the puzzle, but there'll be a lot more contention for the shared resource (the pile of puzzle pieces) and a lot more communication at the interfaces.
- So y'all will get noticeably less than a 4-to-1 speedup, but you'll still have an improvement, maybe something like 3-to-1: the four of you can get it done in 20 minutes instead of an hour.



# Diminishing Returns



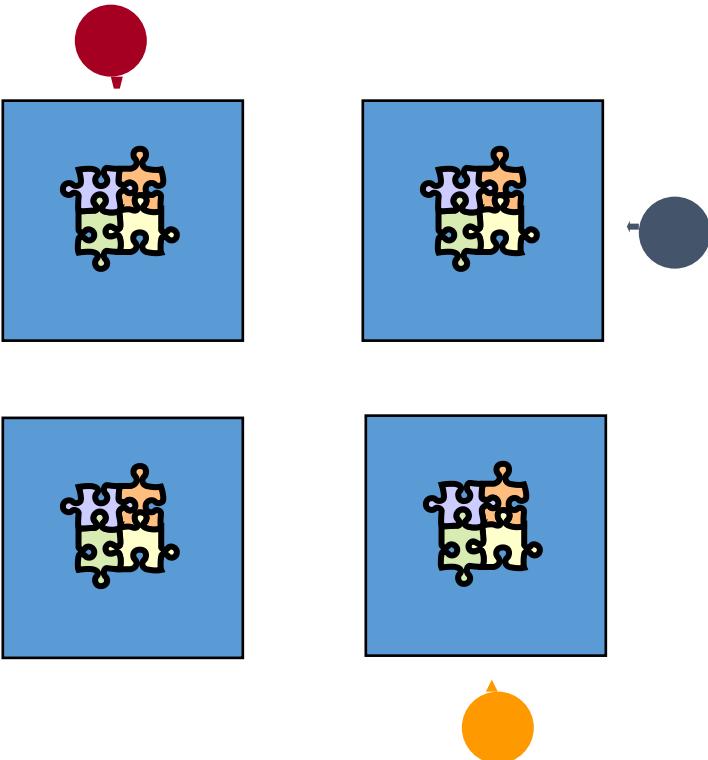
- If we now put Dave and Tom and Horst and Brandon on the corners of the table
- there's going to be a whole lot of contention for the shared resource, and a lot of communication at the many interfaces.
- So the speedup y'all get will be much less than we'd like; you'll be lucky to get 5-to-1.
- So we can see that adding more and more workers onto a shared resource is eventually going to have a diminishing return.

# Distributed Parallelism



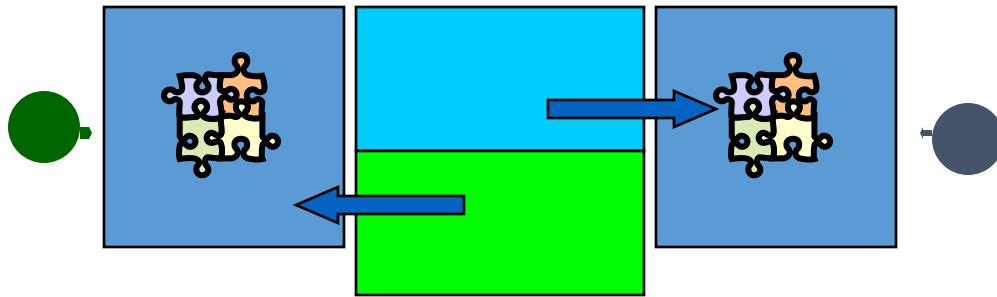
- Now let's try something a little different. Let's set up two tables, and let's put you at one of them and Scott at the other. Let's put half of the puzzle pieces on your table and the other half of the pieces on Scott's. Now y'all can work completely independently, without any contention for a shared resource. **BUT**, the cost per communication is **MUCH** higher (you have to scootch your tables together), and you need the ability to split up (**decompose**) the puzzle pieces reasonably evenly, which may be tricky to do for some puzzles.

# More Distributed Processors



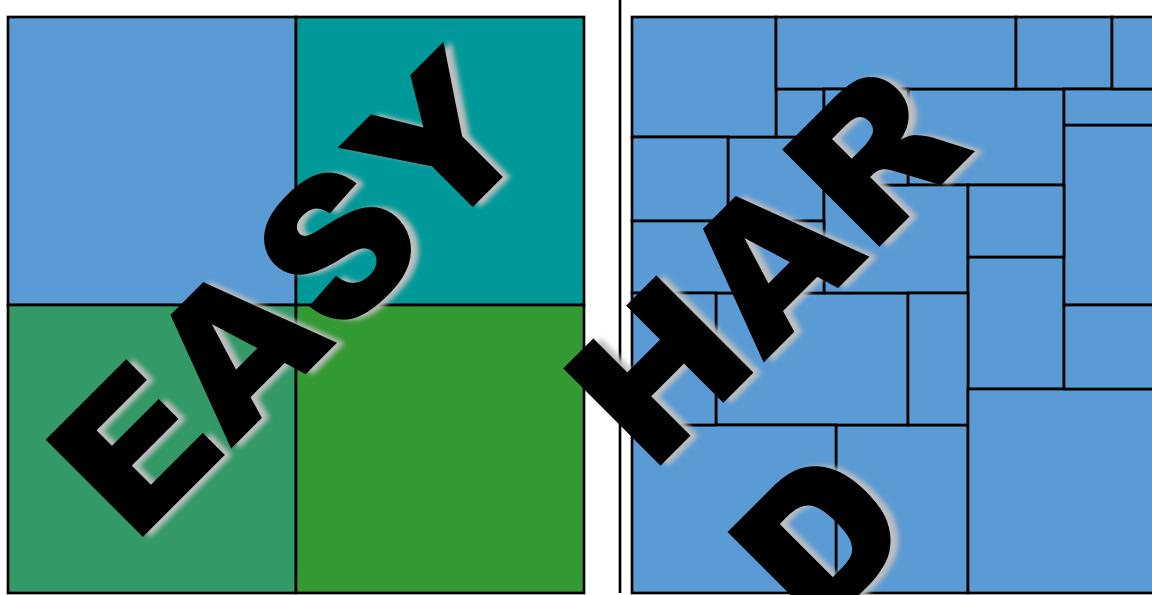
- It's a lot easier to add more processors in distributed parallelism. But, you always have to be aware of the need to decompose the problem and to communicate among the processors.
- Also, as you add more processors, it may be harder to load balance the amount of work that each processor gets.

# Load Balancing



- **Load balancing** means ensuring that everyone completes their workload at roughly the same time.
- For example, if the jigsaw puzzle is half grass and half sky, then you can do the grass and Scott can do the sky, and then y'all only have to communicate at the horizon – and the amount of work that each of you does on your own is roughly equal. So you'll get pretty good speedup.

# Load Balancing



- Load balancing can be easy, if the problem splits up into chunks of roughly equal size, with one chunk per processor. Or load balancing can be very hard.

# Why HPC is Worth the Bother

- What HPC gives you that you won't get elsewhere is the ability to do bigger, better, more exciting science. If your code can run faster, that means that you can tackle much bigger problems in the same amount of time that you used to need for smaller problems.
- HPC is important not only for its own sake, but also because what happens in HPC today will be on your desktop in about 10 to 15 years and on your cell phone in 25 years: it puts you ahead of the curve.

# **Gateways *abstract* these details from Users**

- Parallelism Types
  - Instruction Level Parallelism
  - Shared Memory Multithreading
  - Distributed Memory Multiprocessing
  - GPU Parallelism
  - Hybrid Parallelism (Shared + Distributed + GPU)
- Gateways pick the right computations paradigm based on the problem.

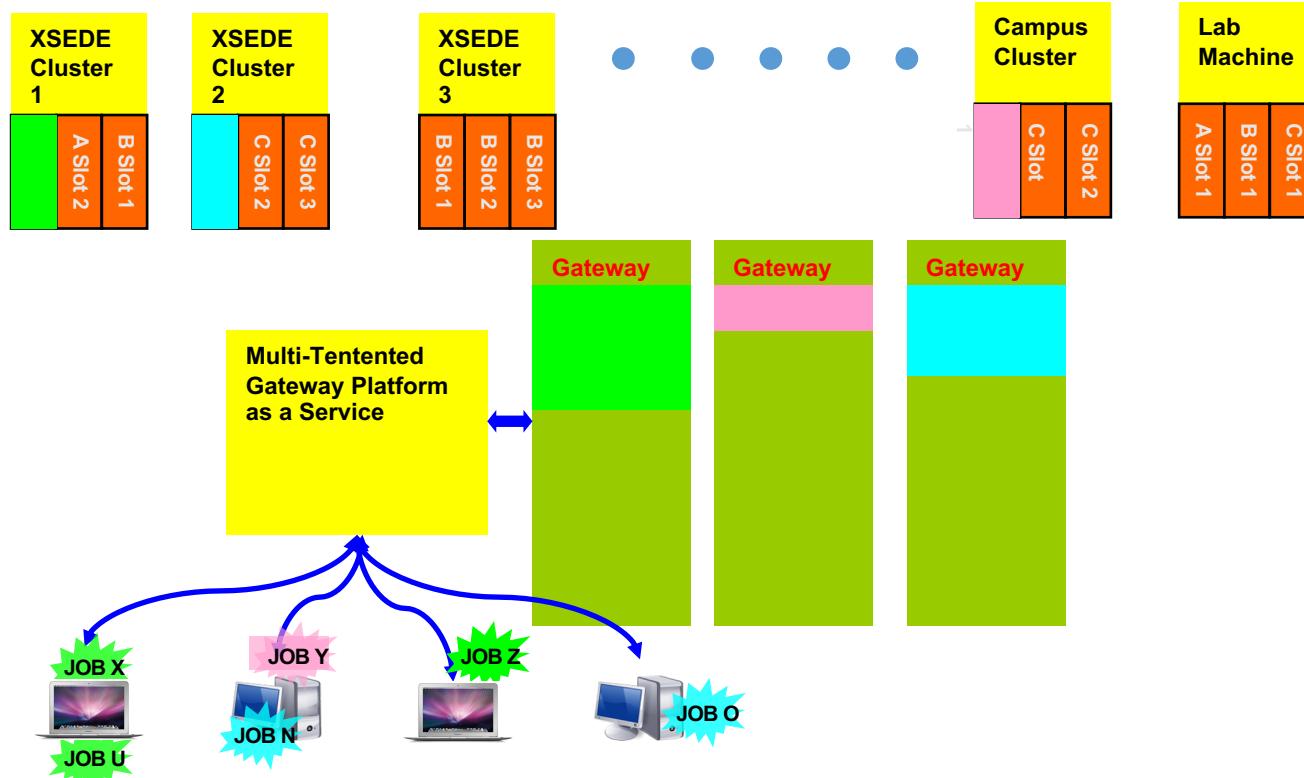
# **Science Gateways**

Unleashing Supercomputing to broad range of users

# Anatomy of a Science Gateway

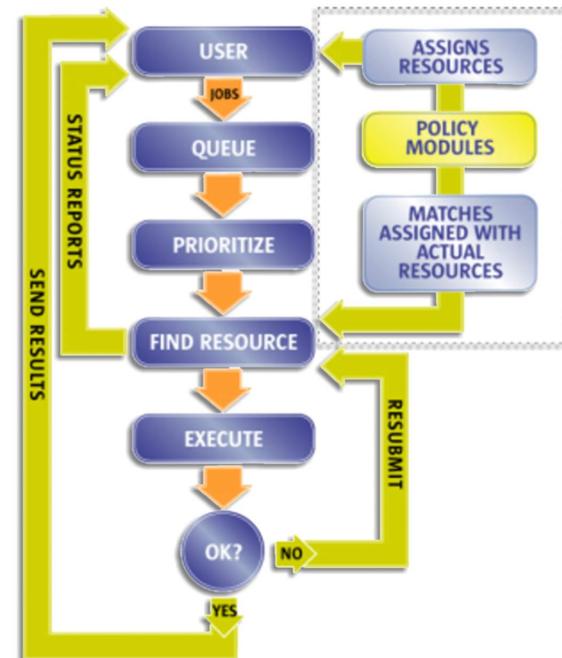
- Gateway User Interface
  - Web Portals
  - Desktop Clients
  - Social/ Collaboration Capabilities
- Security Infrastructure
- Analyses & Visualization Capabilities
- Execution Frameworks
  - Application Abstraction
  - Workflow construction & Enactment
  - Compute Resource Management
  - Scheduling
  - Messaging System
- Data Management
- Provenance Collection

# Science Gateways Federate Jobs across clusters

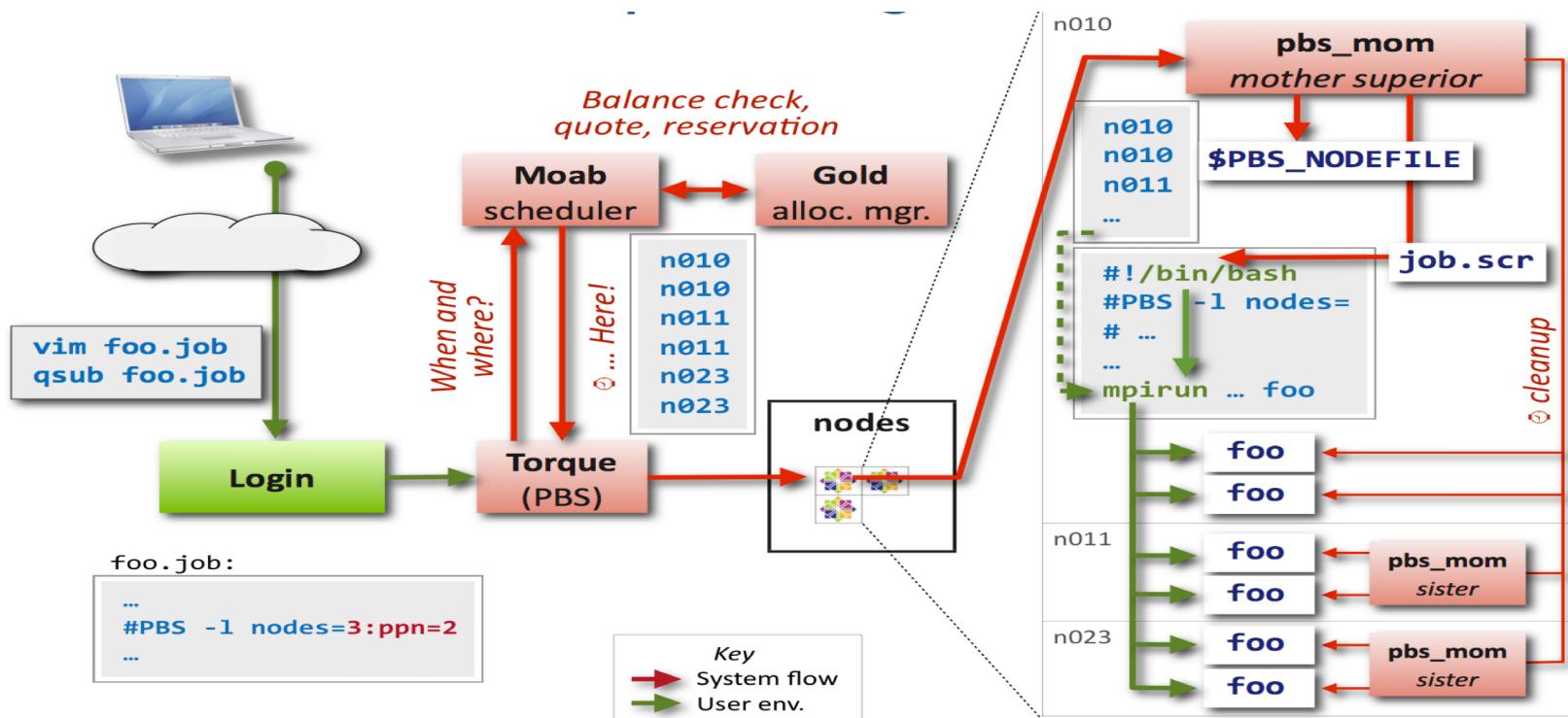


# Resource Batch Managers

- Dynamic Resource Management
  - Job Scheduling
  - Resource monitoring
  - Policy administration
  - User authentication and access control
  - Accounting and reporting
- Popular Tools
  - SLURM
  - PBS



# Job Managers Flow



# Apache Airavata

# Airavata Overview

- Airavata is a general purpose distributed system software framework build on micro-service and component based architecture principles.
- Airavata provides capabilities to compose, manage, execute and monitor large scale applications and workflows on distributed computing resources.
- Airavata supports executions on local clusters, national grids, academic and commercial clouds.
- Airavata is inherently multi-tenanted.

# Airavata as a Science Gateway Middleware

- Airavata is dominantly used to build science gateways.
- Airavata supports secured communications to HPC resources and empowers gateway operators to administer and monitor long running executions.
- A Django based portal front-end illustrates Airavata capabilities.

