The Swift scripting language for Science Clouds

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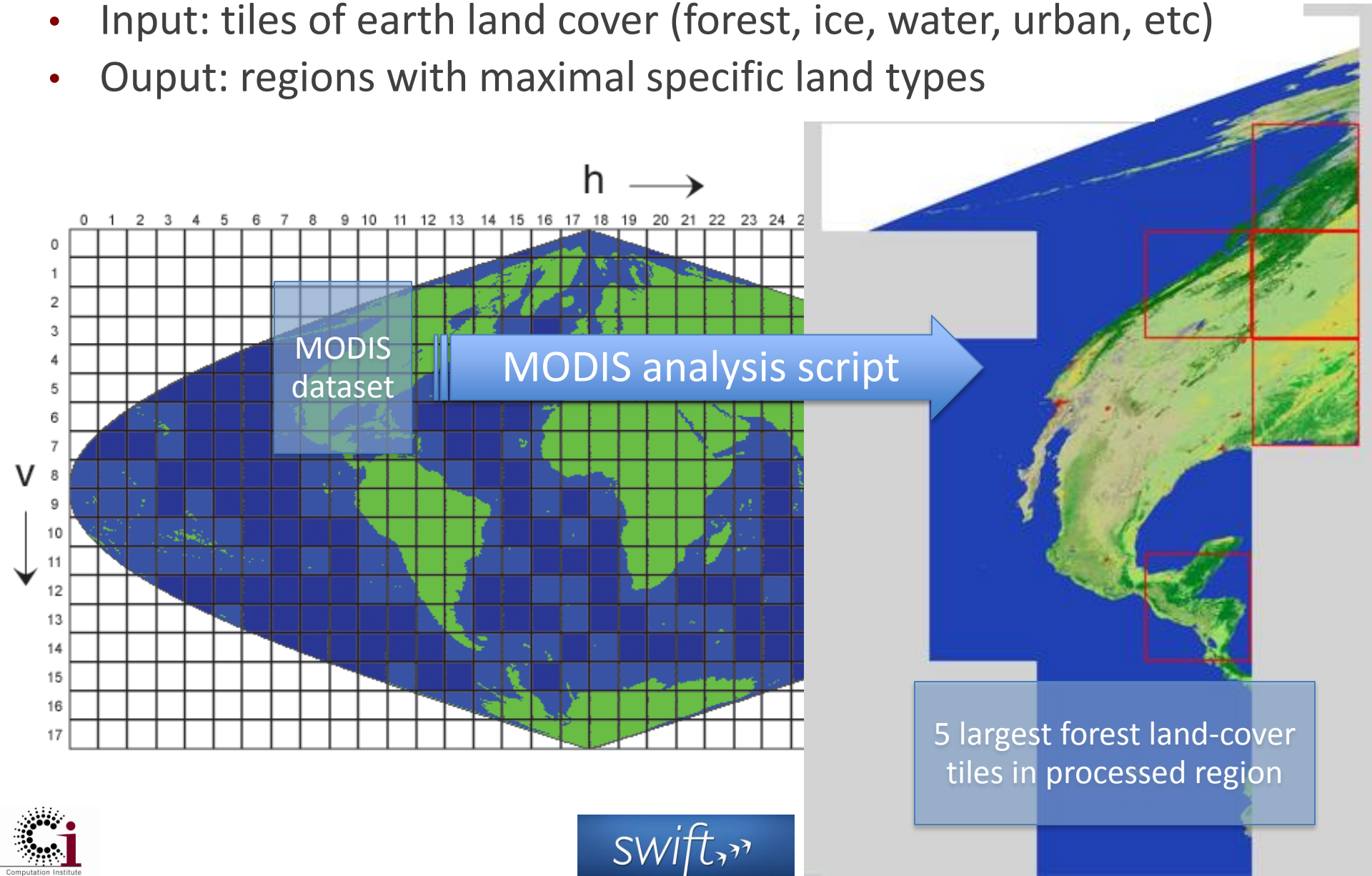
*www.ci.uchicago.edu/*swift

Context

- You've heard this afternoon how to run Science work in Clouds
- *But further challenges need to be addressed:*
  - *Running applications with data dependencies that require complex pipelines*
  - *Moving data fast and automatically*
  - *Dynamic*ally *changing size* of provisioned resource pools
  - *Handling failures* of nodes, networks, application stacks

Example – MODIS satellite image processing

- Input: tiles of earth land cover (forest, ice, water, urban, etc)
- Ouput: regions with maximal specific land types



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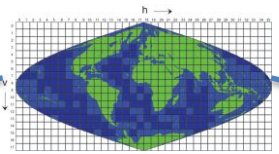
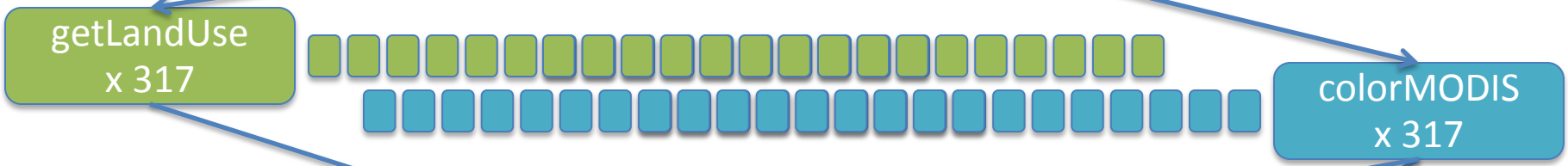
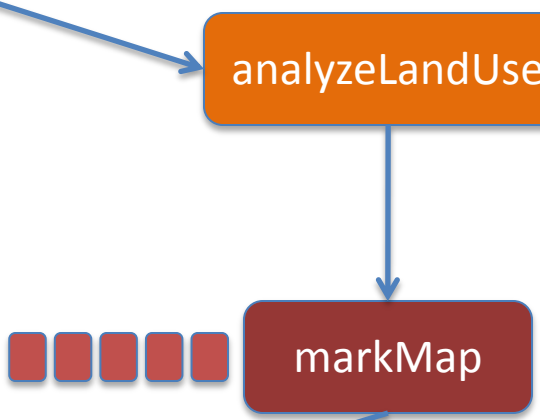
Goal: Run MODIS processing pipeline in cloud

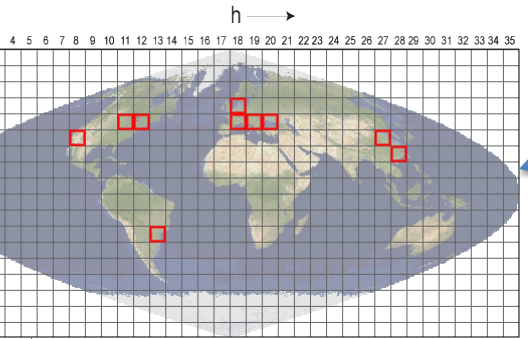
MODIS script is automatically run in parallel:

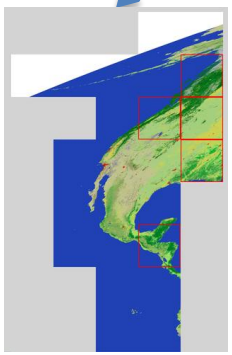




Each loop level can process tens to thousands of image files.







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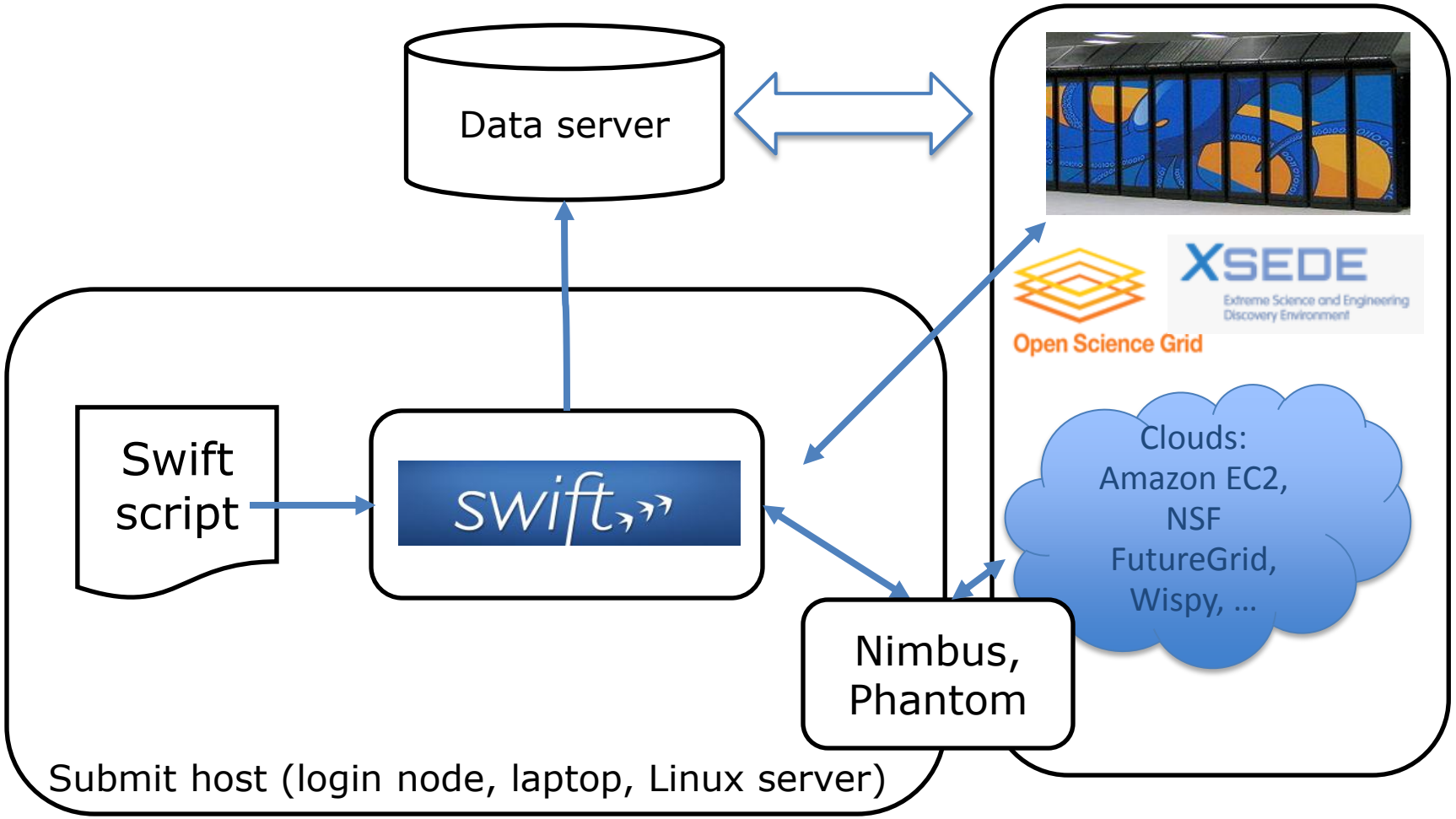
Solution: Swift parallel distributed scripting



Swift runs parallel scripts on cloud resources provisioned by Nimbus's *Phantom* service.

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Features overview

- **Swift is a parallel scripting language** for multicores, clusters, grids, clouds, and **supercomputers**
  - *for loosely-coupled "many-task" applications – programs and tools linked by exchanging files*
  - *debug on a laptop, then run on a large system*
- **Swift is easy to write**
  - *a simple high-level functional language with C-like syntax*
  - *Small Swift scripts can do large-scale work*
- **Swift is easy to run**: contains all services for running the workflow - in one Java application
  - *untar and run – Swift acts as a self-contained grid or cloud client*
  - ***Swift automatically runs scripts in parallel** – typically without user declarations*
- **Swift is fast**: based on a powerful, efficient, scalable and flexible Java execution engine
  - *scales readily to millions of tasks*
- **Swift is general purpose**:
  - *applications in neuroscience, proteomics, molecular dynamics, biochemistry, economics, statistics, earth systems science, and beyond.*

MODIS script in Swift: main data flow

```
foreach g,i in geos {
    land[i] = getLandUse(g,1);
}
(topSelected, selectedTiles) =
    analyzeLandUse(land, landType, nSelect);

foreach g, i in geos {
  colorImage[i] = colorMODIS(g);
}
gridMap = markMap(topSelected);
montage =
   assemble(selectedTiles,colorImage,webDir);
```

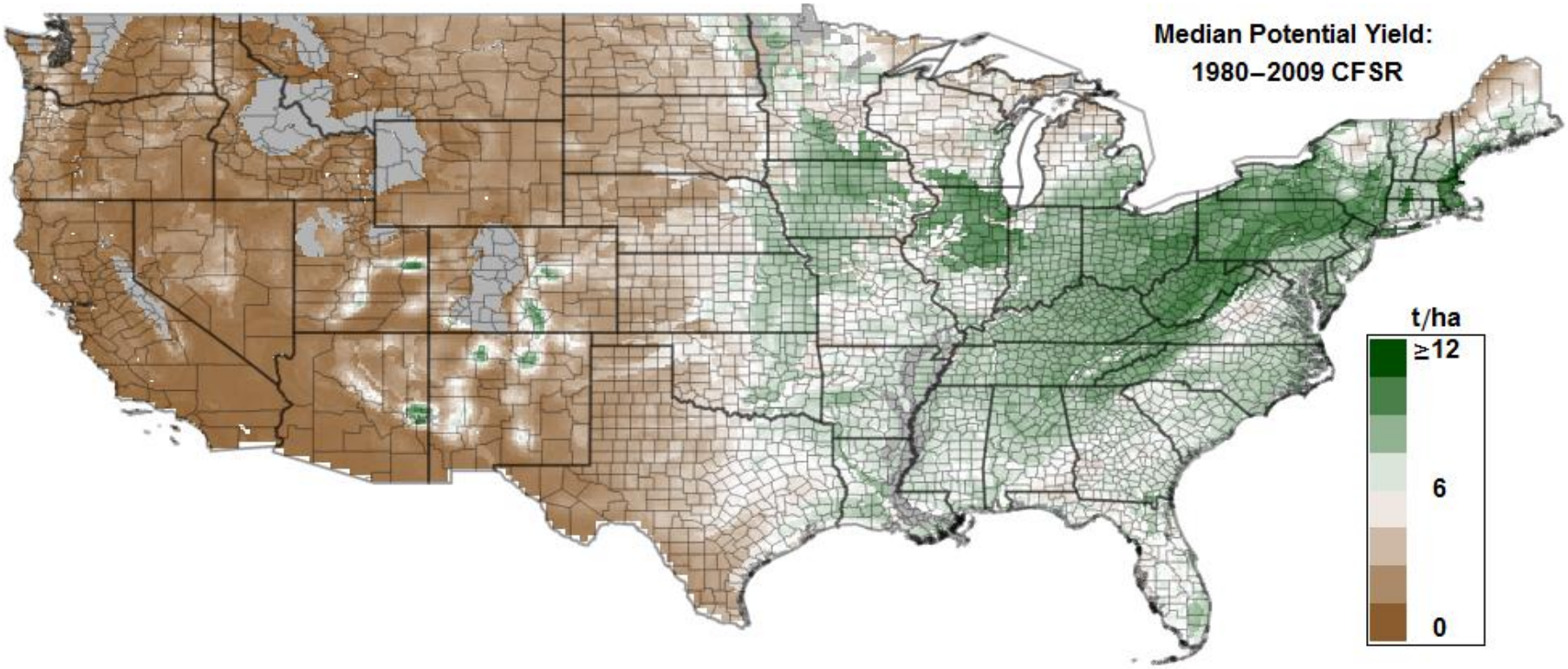
Demo of Nimbus-Phantom-Swift on FutureGrid

- User provisions 5 nodes with Phantom
  - Phantom starts 5 VMs
  - Swift worker agents in VMs contact Swift coaster service to request work
- Start Swift application script “MODIS”
  - Swift places application jobs on free workers
  - Workers pull input data, run app, push output data
- 3 nodes fail and shut down
  - Jobs in progress fail, Swift retries
- User can add more nodes with phantom
  - User asks Phantom to increase node allocation to 12
  - Swift worker agents register, pick up new workers, runs more in parallel
- Workload completes
  - Science results are available on output data server
  - Worker infrastructure is available for new workloads

Swift and Phantom provide fault tolerance

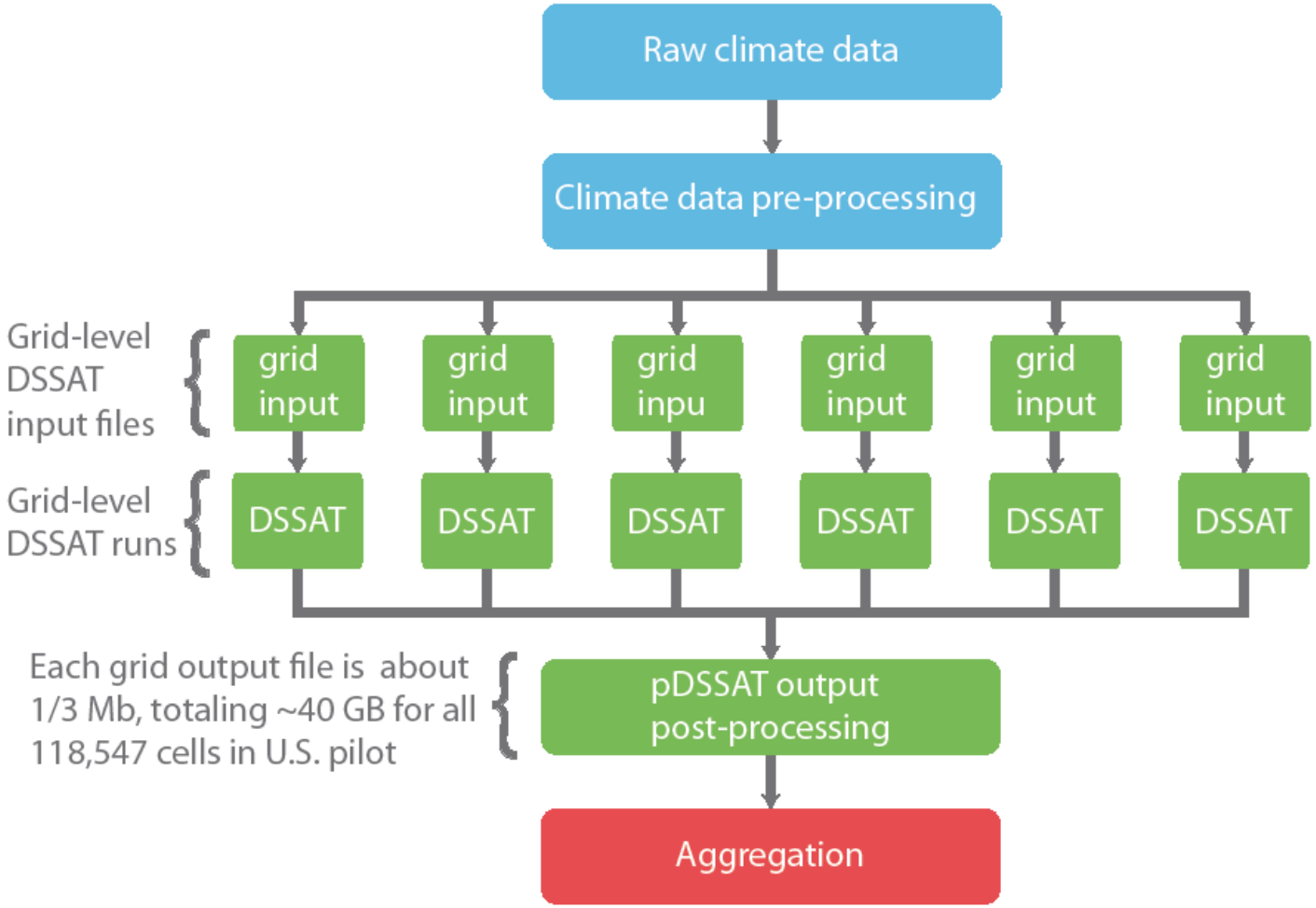
- Phantom detects downed nodes and re-provisions
- Swift can retry jobs
  - Up to a user specified limit
  - Can stop on first unrecoverable failure, or continue till no more work can be done
  - Very effective, since Swift can break workflow into many separate scheduler jobs, hence smaller failure units
- Swift can replicate jobs
  - If jobs don't complete in a designated time window, Swift can send copies of the job to other sites or systems
  - The first copy to succeed is used, other copies are removed
- Each app() job can define "failure"
  - Typically non-zero return code
  - Wrapper scripts can decide to mask app() failures and pass back data/logs about errors instead

Land use studies - DSSAT



Median 1980-2009 corn yields (metric tons per hectare) as simulated by Decision Support System for Agrotechnology Transfer (DSSAT) driven by National Center for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR).

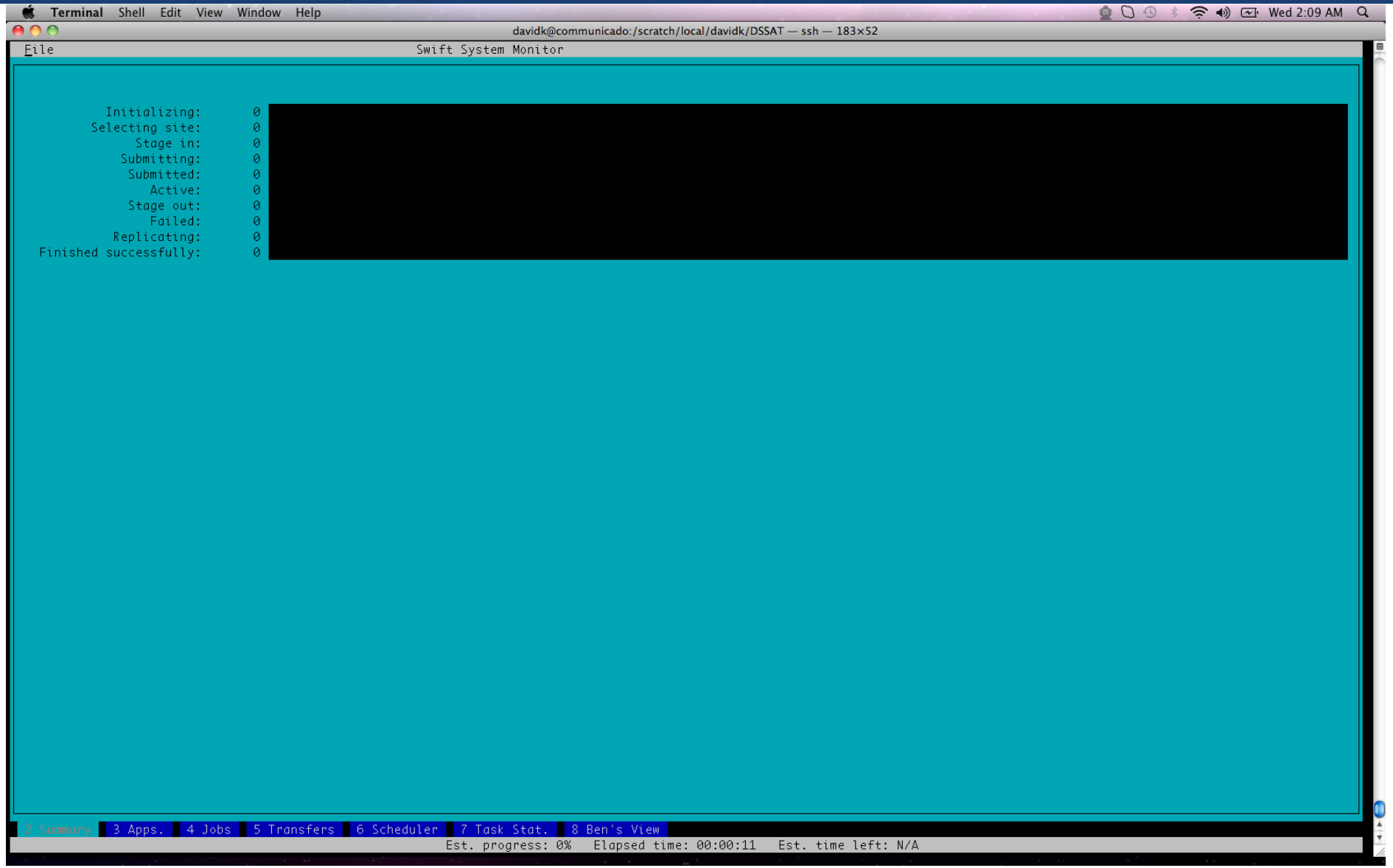
DSSAT – workflow schematic



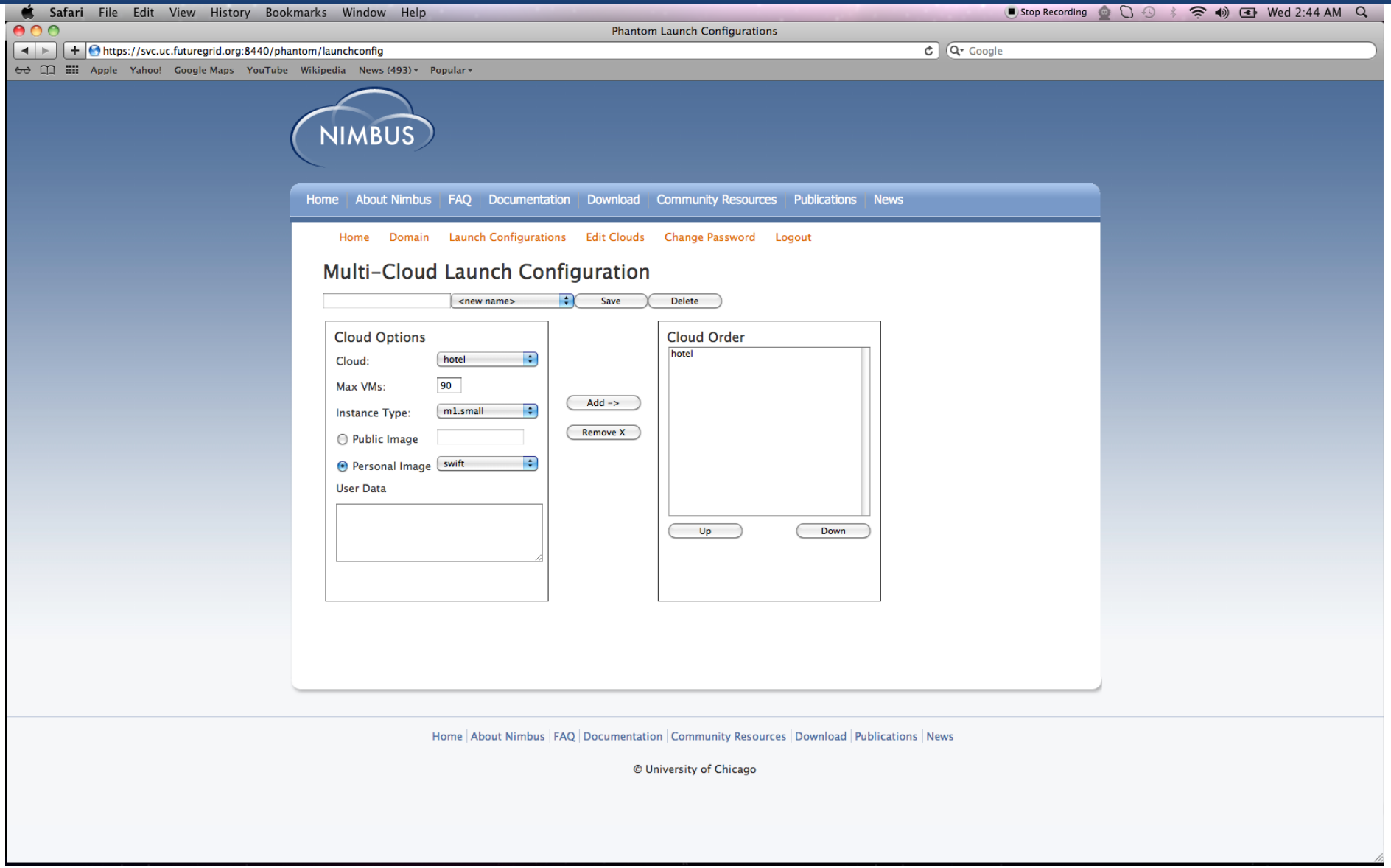
DSSAT

- *Let's run it*

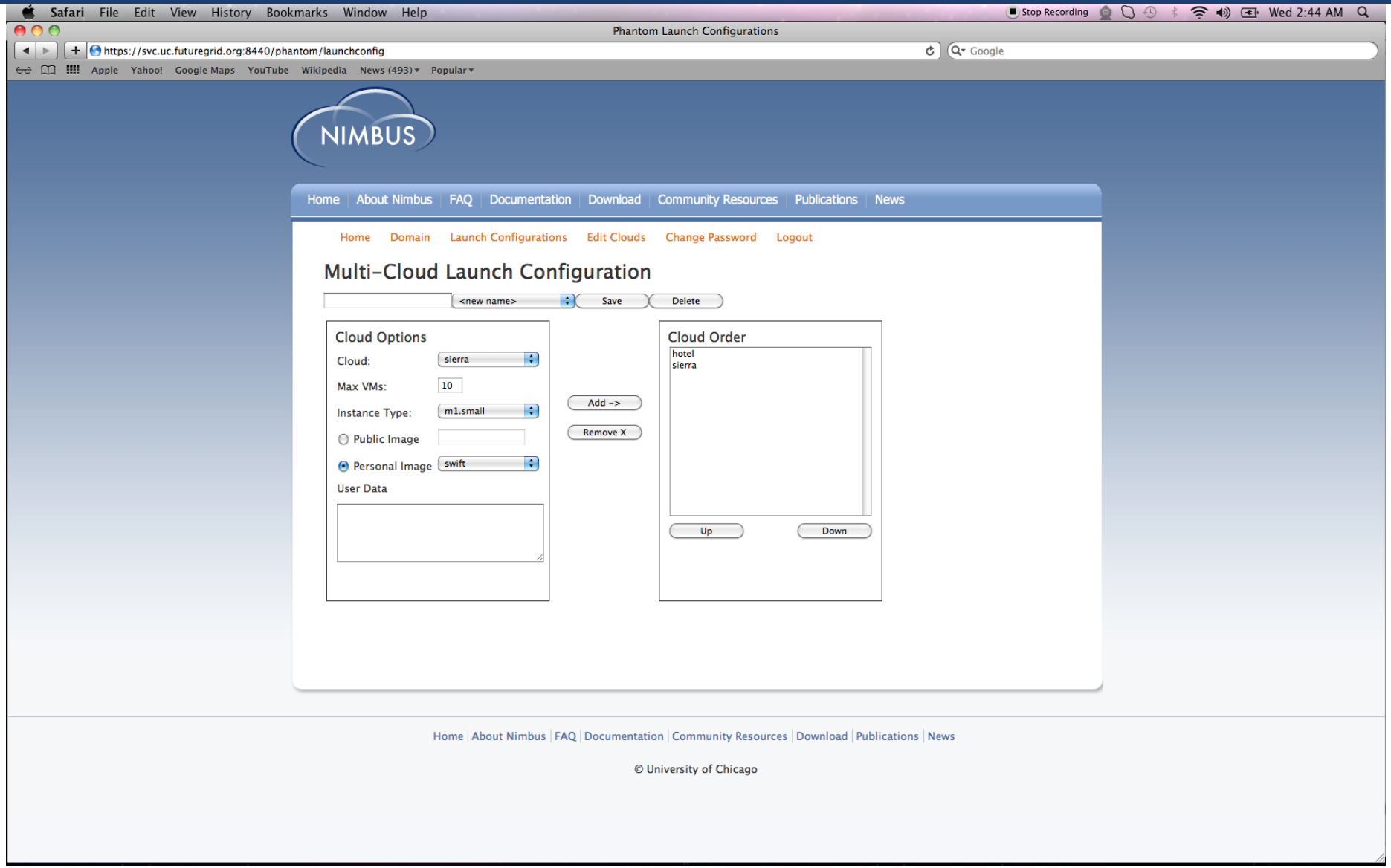
Swift's Text User Interface (TUI) – Initial State



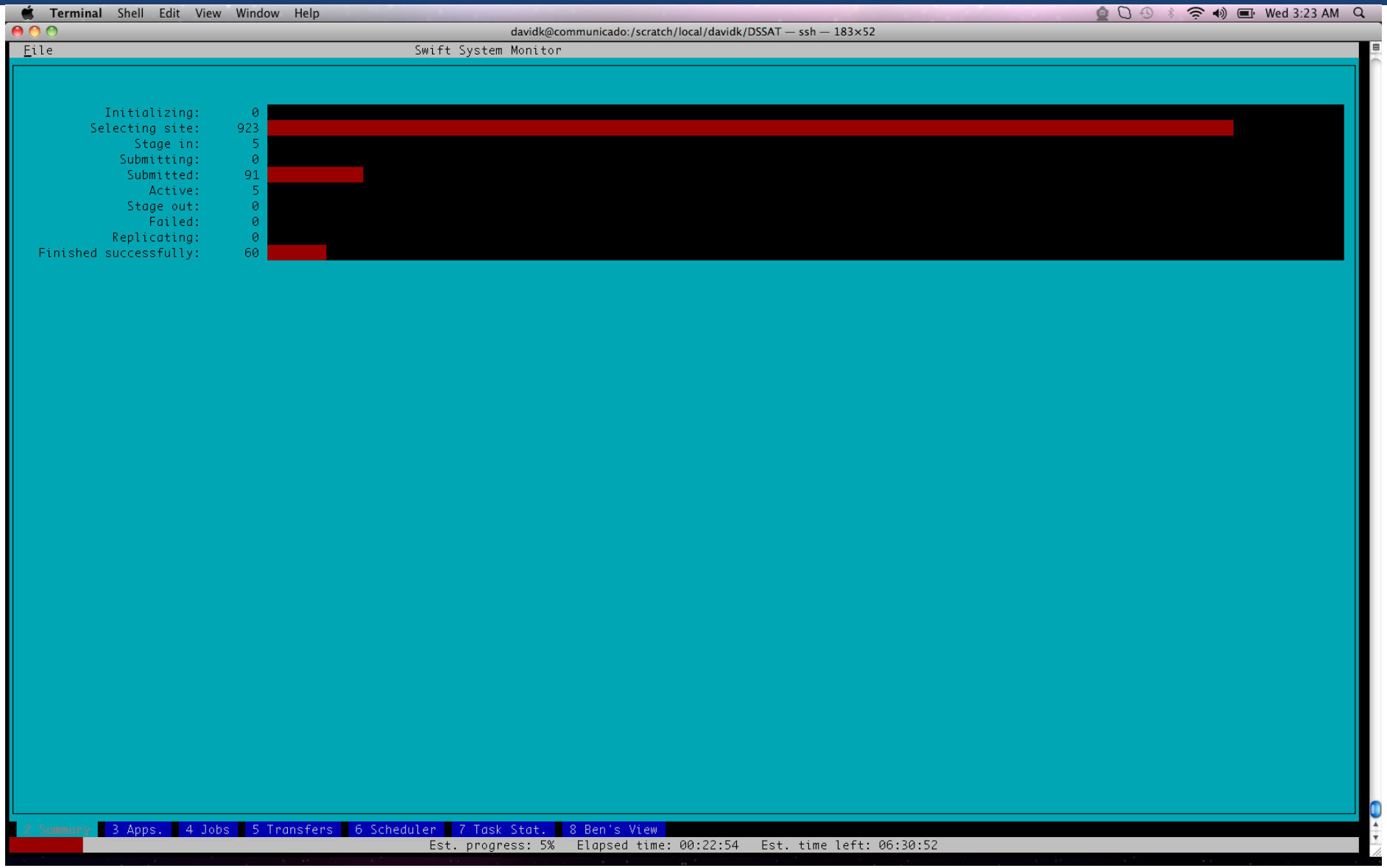
Provide nodes to Swift from ‘hotel’



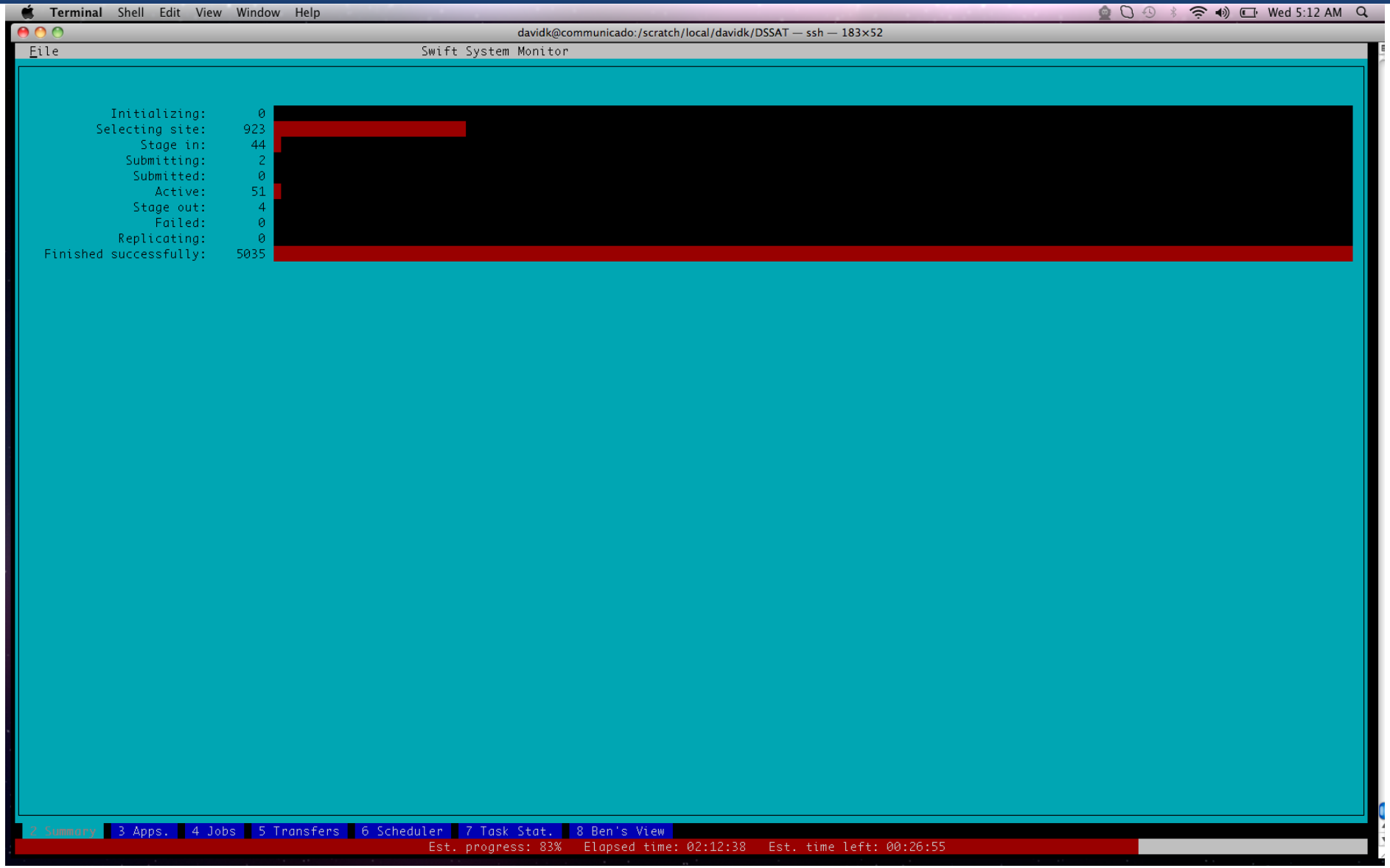
Add 10 more nodes from ‘sierra’



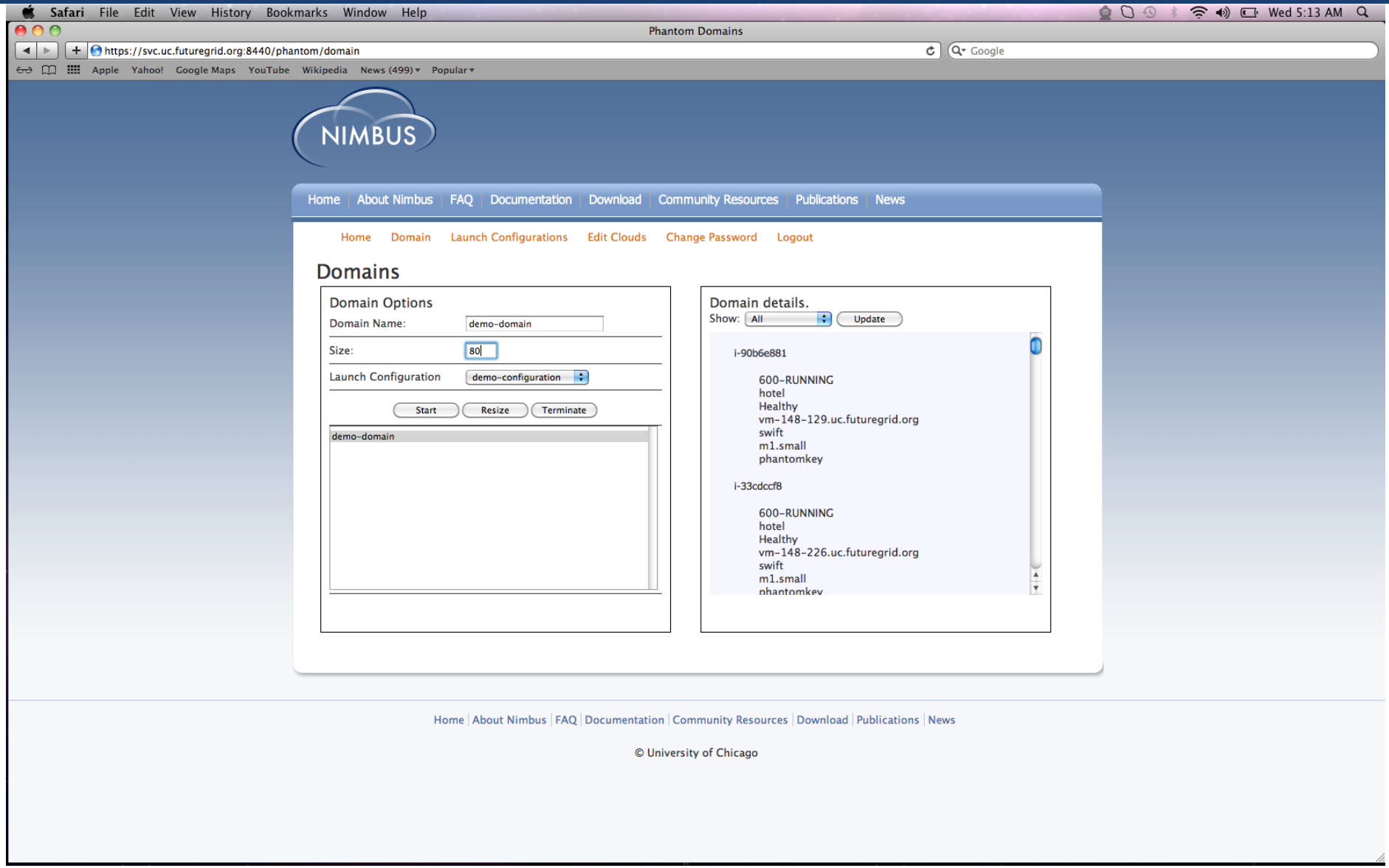
Swift starts running jobs…



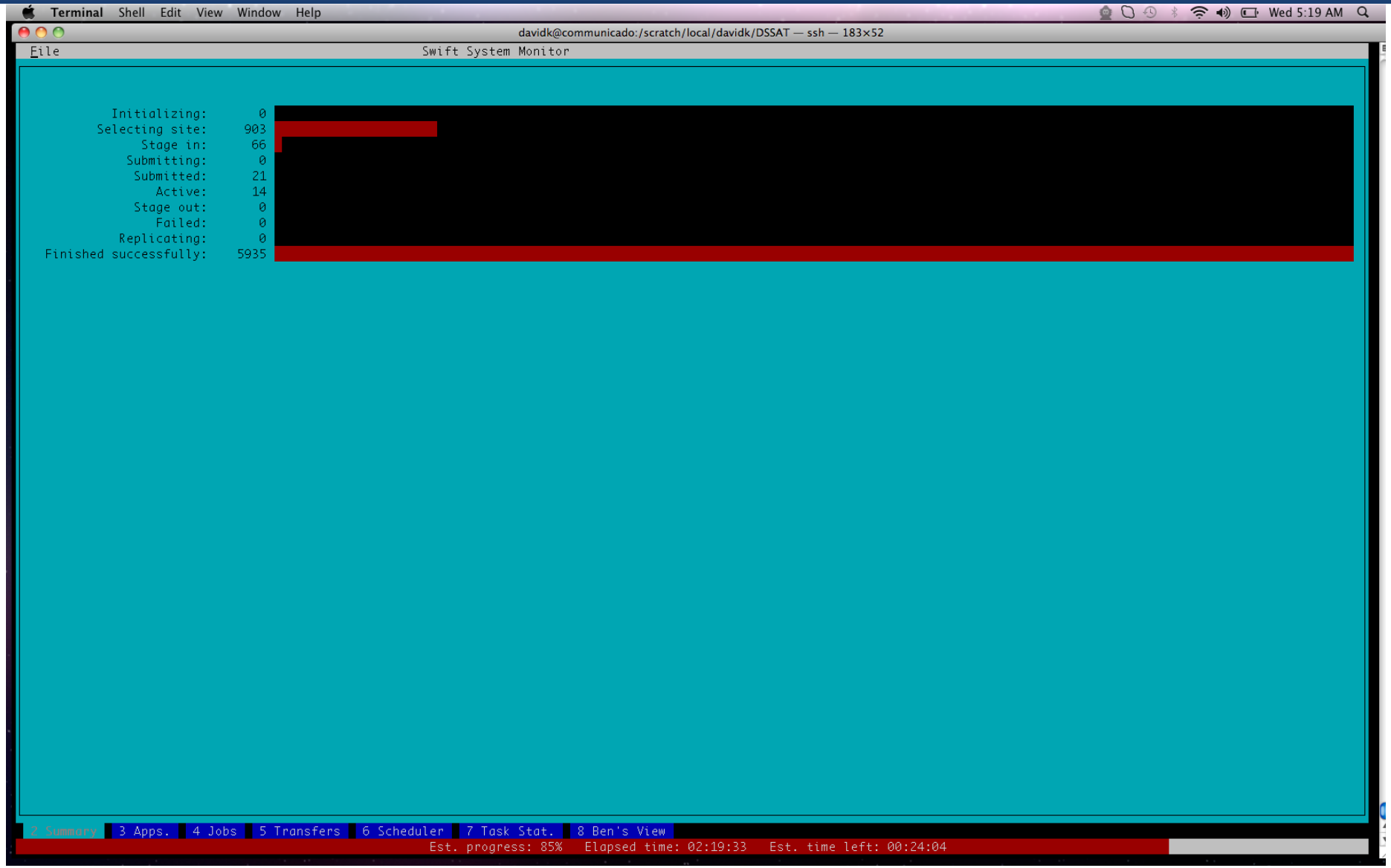
Swift continues (2 hours later)



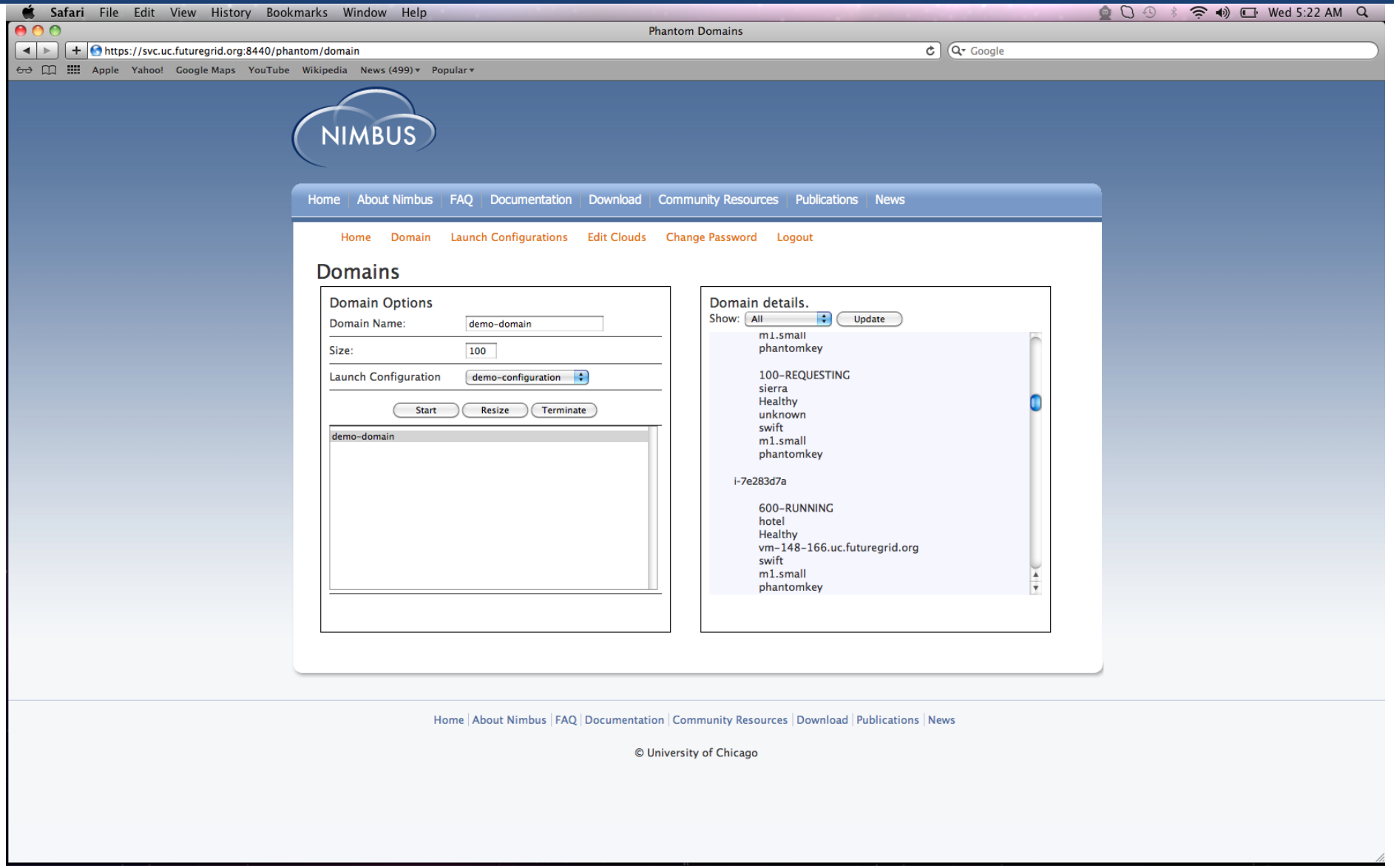
Forcibly terminate some of Swifts' resources



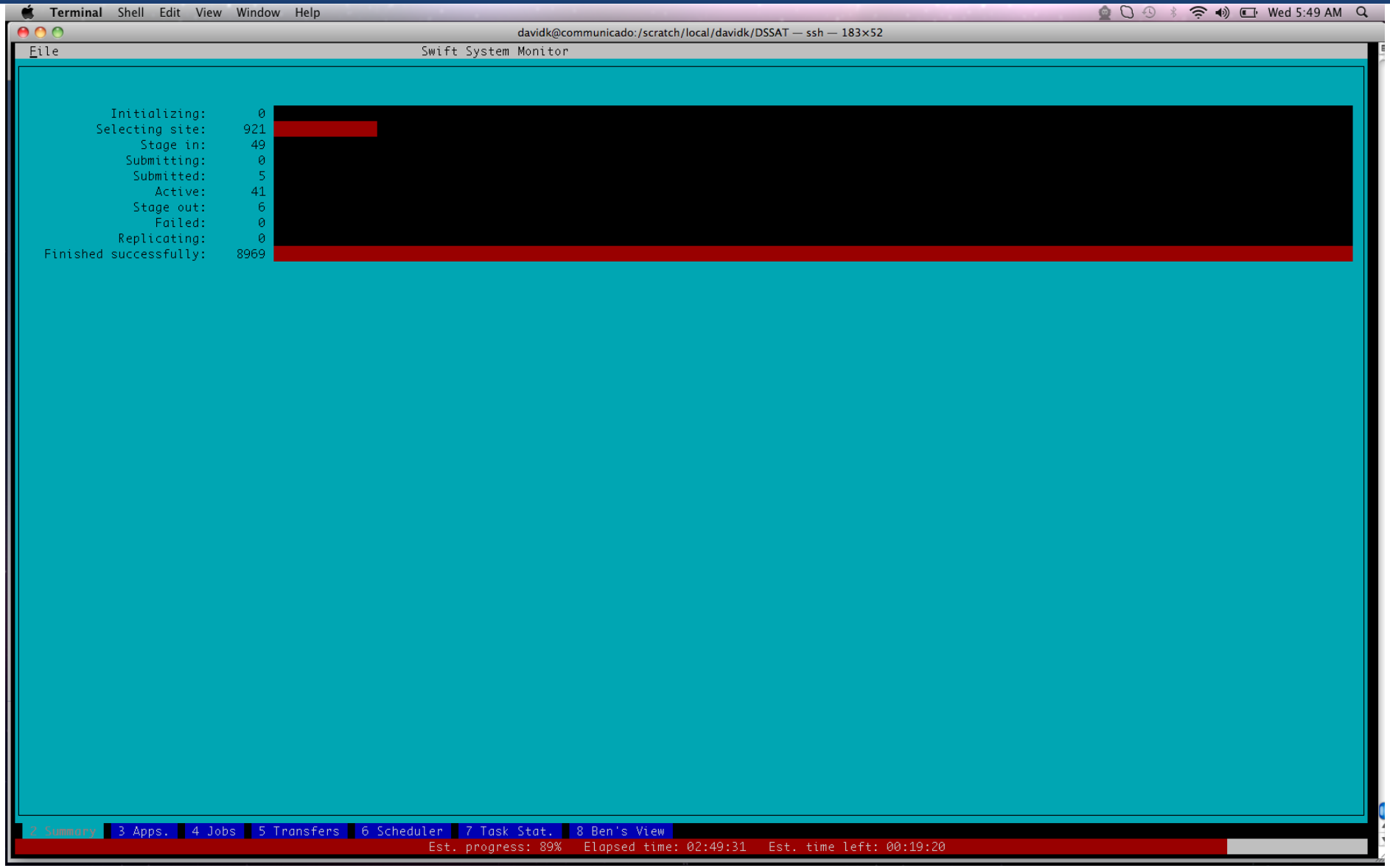
Swift chugs along…



Restore Swift's compute nodes



Swift proceeds to completion.



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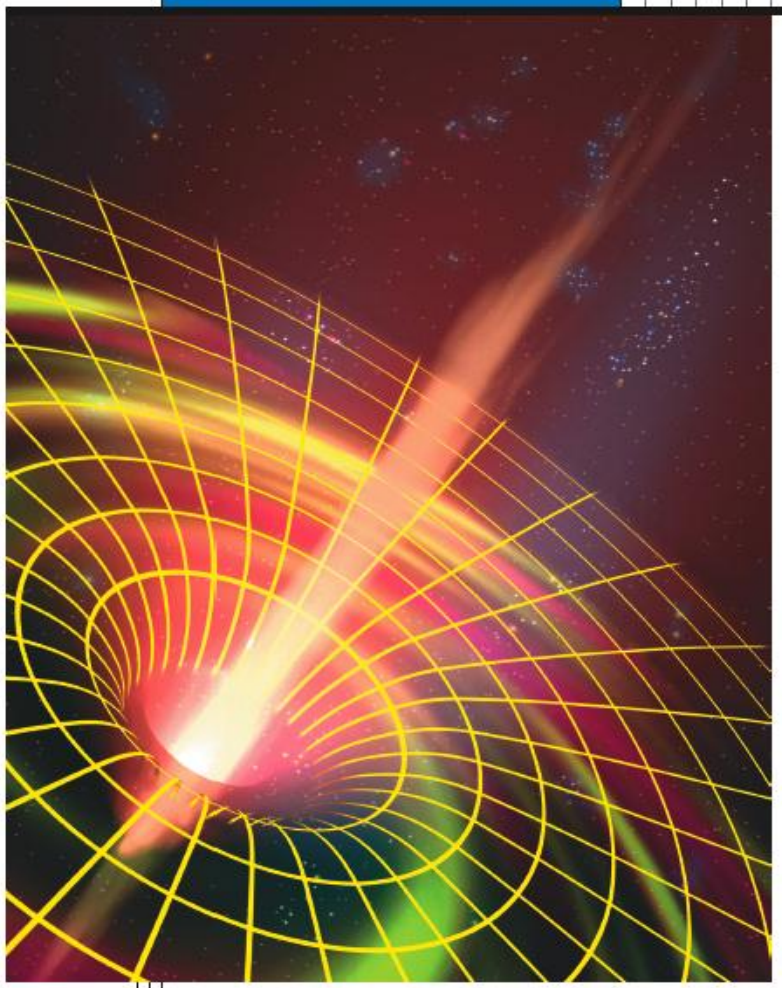

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Swift: A language for distributed parallel scripting

Michael Wilde [a,b,*], Mihael Hategan [a], Justin M. Wozniak [b], Ben Clifford [d], Daniel S. Katz [a], Ian Foster [a,b,c]

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ABSTRACT

Scientists, engineers, and statisticians must execute domain-specific application programs many times on large collections of file-based data. This activity requires complex orchestration and data management as data is passed to, from, and among application invocations. Distributed and parallel computing resources can accelerate such processing, but their use further increases programming complexity. The Swift parallel scripting language reduces these complexities by making file system structures accessible via language constructs and by allowing ordinary application programs to be composed into powerful parallel scripts that can efficiently utilize parallel and distributed resources. We present Swift's implicitly parallel and deterministic programming model, which applies external applications to file collections using a functional style that abstracts and simplifies distributed parallel execution.

Parallel Computing, Sep 2011

Acknowledgments

- Swift is supported in part by NSF grants OCI-1148443, OCI-721939, OCI-0944332, and PHY-636265, NIH DC08638, DOE and UChicago LDRD and SCI programs

- The Swift team (including some related projects) is:
  - Mihael Hategan, Justin Wozniak, David Kelly, Ian Foster, Dan Katz, Mike Wilde, Tim Armstrong, Zhao Zhang

Questions?

Supplementary slides

MODIS script: declare data and external science apps

```
type file;
type imagefile;
type landuse;

app (landuse output) getLandUse (imagefile input, int sortfield)
{ getlanduse @input sortfield stdout=@output ; }

app (file output, file tilelist) analyzeLandUse
    (landuse input[], string usetype, int maxnum)
{ analyzelanduse @output @tilelist usetype maxnum @filenames(input); }

app (imagefile output) colorMODIS (imagefile input)
{ colormodis @input @output; }

app (imagefile output) assemble
    (file selected, imagefile image[], string webdir)
{ assemble @output @selected @filename(image[0]) webdir; }

app (imagefile grid) markMap (file tilelist)
{ markmap @tilelist @grid; }

int nFiles =      @toint(@arg("nfiles","1000"));
int nSelect =     @toint(@arg("nselect","12")); ...
```

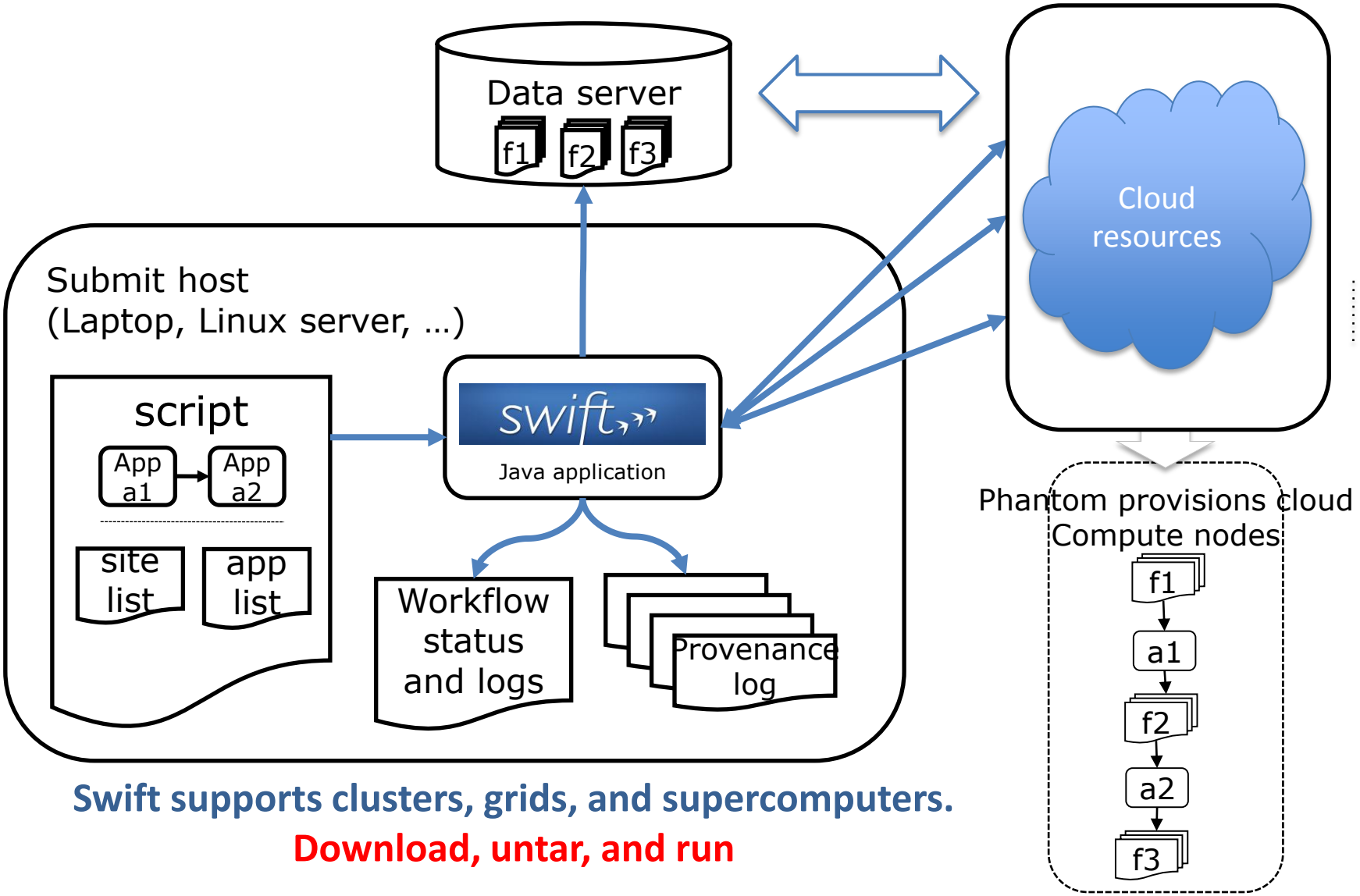
MODIS script: compute land use and max usage

```
imagefile geos[] <ext; exec="modis.mapper",      # Input Dataset
  location=MODISdir, suffix=".tif", n=nFiles >;

# Compute the land use summary of each MODIS tile

landuse land[] <structured_regexp_mapper; source=geos, match="(h..v..)",
  transform=@strcat(runID,"/\\1.landuse.byfreq")>;

foreach g,i in geos {
    land[i] = getLandUse(g,1);
}

# Find the top N tiles (by total area of selected landuse types)

file topSelected<"topselected.txt">;
file selectedTiles<"selectedtiles.txt">;
(topSelected, selectedTiles) = analyzeLandUse(land, landType, nSelect);
```

MODIS script: render data to display

```
# Mark the top N tiles on a sinusoidal gridded map

imagefile gridMap<"markedGrid.gif">;
gridMap = markMap(topSelected);

# Create multi-color images for all tiles

imagefile colorImage[] <structured_regexp_mapper;
        source=geos, match="(h..v..)",
        transform="landuse/\\1.color.png">;

foreach g, i in geos {
  colorImage[i] = colorMODIS(g);
}

# Assemble a montage of the top selected areas
imagefile montage <single_file_mapper; file=@strcat(runID,"/","map.png") >; # @arg
montage = assemble(selectedTiles,colorImage,webDir);
```

Runtime to execute Swift apps in the Cloud



Swift supports clusters, grids, and supercomputers.

Download, untar, and run

Examples of other Swift many-task applications

A. Simulation of super-cooled glass materials

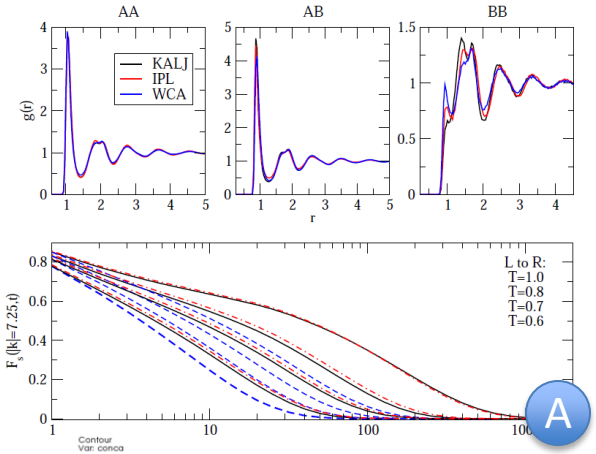
B. Protein folding using homology-free approaches

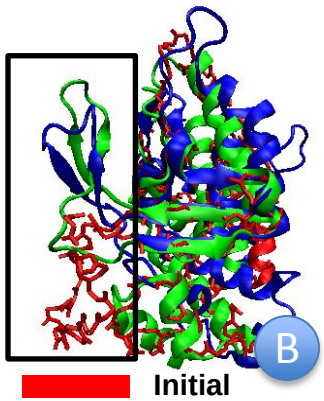
C. Decision making in climate and energy policy

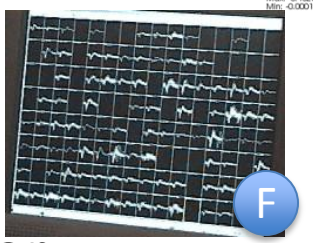
D. Simulation of RNA-protein interaction

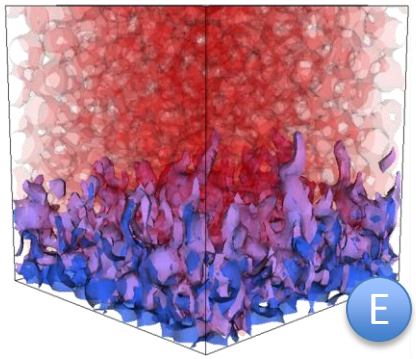
E. Multiscale subsurface modeling on Hopper

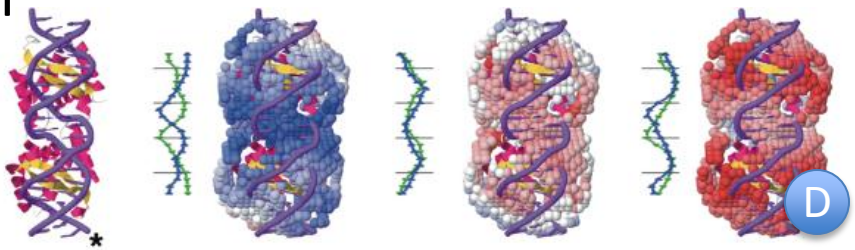
F. Modeling framework for statistical analysis of neuron activation

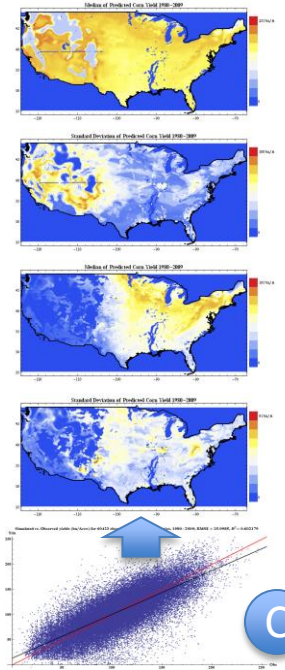












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Summary

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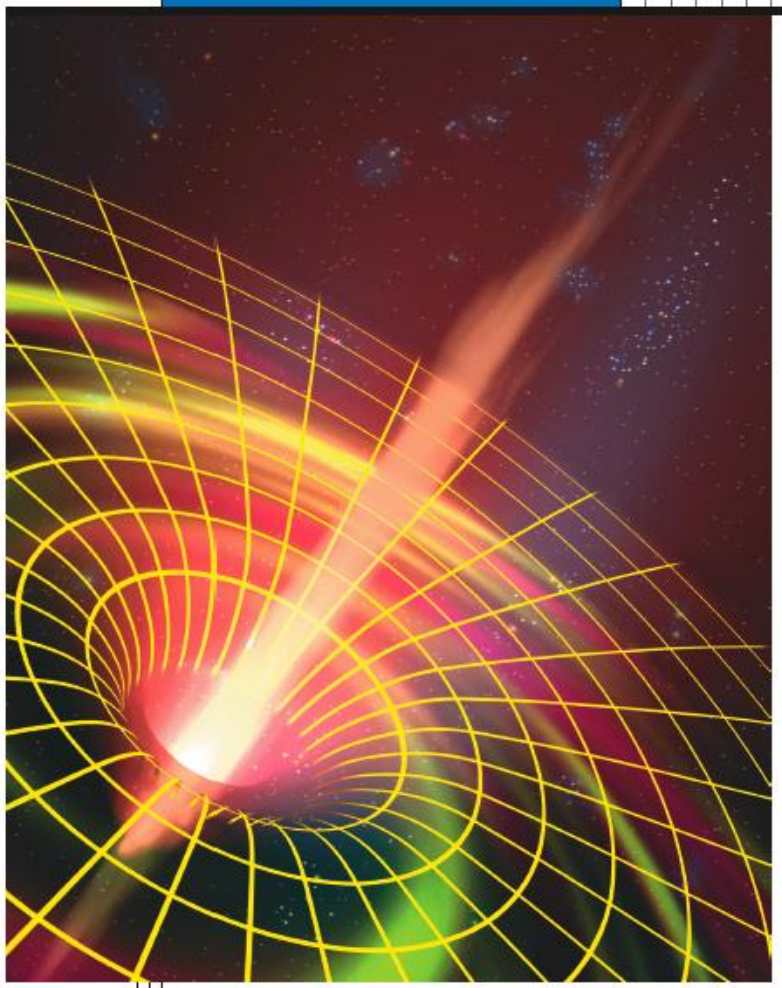

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