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# Employing a Software-Driven Approach to Scalable HPC System Management

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# HPC System Management is Challenging

## HPC Scale & Complexity

- Multi HPC system management
  - Over 30 allocatable HPE and non-HPE systems
- Thousands of users & research projects
- Massive resource allocations and enforcement
- Filesystem and permission management
- Identity and access management
  - Multi-system authentication (LDAP, OneID, XCAMS)

## Operational Scale Challenges

- Manual processes don't scale & admin burden increases as systems and capabilities grow
- Our software supports the business of running HPC systems at our scale and complexity



# System Management Progression

## Line-by-Line Configuration

```
ilorest createuser "my_new_user" "password123" --role  
  Login,RemoteConsole  
useradd -m my_new_user  
passwd my_new_user  
groupadd user_group  
usermod -aG user_group my_new_user  
groupadd project123  
# Additional group commands here  
usermod -aG project007 my_new_user  
mkdir -p /gpfs/project123/my_new_user  
chown my_new_user:project123  
/gpfs/project123/my_new_user  
...
```

## Abstracting with Bash Scripts

```
bash ./create_user.sh \  
--username "my_new_user" \  
--password "password123" \  
--groups "user_group,project123,project007" \  
--directories  
"/gpfs/project123/my_new_user,/hpss/project007  
/my_new_user" \  
--with-filesystem \  
--with-home-directory \  
--with-directory-permissions
```

# Problems with Manual System Configuration

## 1. Inconsistent Configuration Across Clusters

- Repeated manual setup across HPC systems is error-prone, time consuming, and leads to drift

## 2. Configuration Complexity

- UNIX users, UNIX groups, filesystems, sudo rules, and scheduler configurations (SLURM and LSF)

## 3. Slow Policy Enforcement

- Manual enforcement delays urgent changes such as ending compute allocations and user access

## 4. No Audit Trail

# OLCF Solution

## RATS CRM

- Handle operations of multiple large-scale HPC systems from a single application
- Authoritative source of truth that defines state of HPC systems via API endpoints

## MyOLCF

- Reduce administrative burden through management and usage insight

## RATS Report

- Near real-time analytics & reporting of system compute & filesystem usage



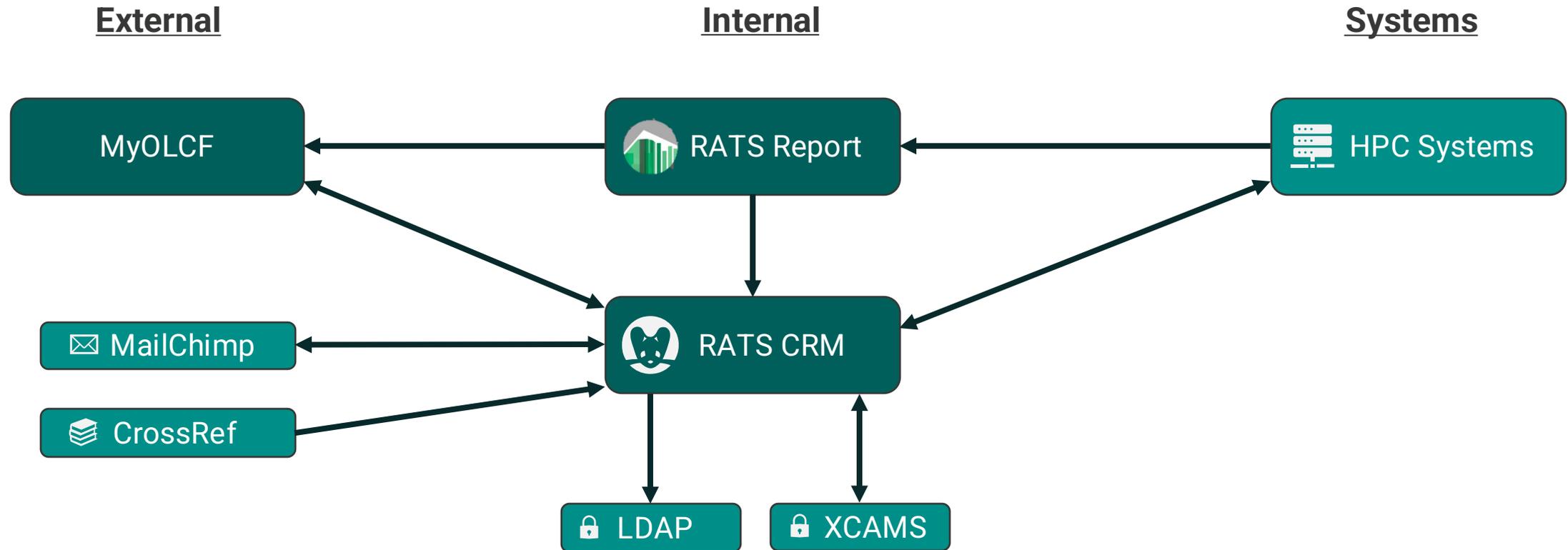
myOLCF



\* **RATS** stands for **R**esource **A**llocation **T**racking **S**ystem

\* **CRM** stands for **C**ustomer **R**elationship **M**anagement

# High-Level RATS CRM, MyOLCF, and HPC Integration



*Arrows denote information flow direction*

# System Architecture Overview

## RATS CRM

### 1. Built With

- Ruby (Rails framework)
- MariaDB

### 2. DevOps & Deployment

- GitLab Runners (CI/CD)
- Kustomize for declarative infrastructure

### 3. History

- Created in 2012
- Replaced legacy C++ and Bash scripts

## RATS Report

### 1. Built With

- Ruby (Rails framework)
- MariaDB

### 2. DevOps & Deployment

- GitLab Runners (CI/CD)
- Kustomize for declarative infrastructure

### 3. History

- Created in 2015

## MyOLCF

### 1. Built With

- JavaScript
- Vue framework

### 2. DevOps & Deployment

- GitLab Runners (CI/CD)
- Kustomize for declarative infrastructure

### 3. History

- Created in 2020

# RATS CRM: Centralizing HPC Operations Management

## 1. Core HPC Management

- Job scheduler configurations
- Filesystem directories
- Node and core allocations
- Identity & security access
- User and system access
- Enforces & automates governance policies

## 2. Data Dissemination

- 224 API endpoints used by HPC systems and services

The screenshot displays the RATS CRM interface. At the top is a navigation bar with the RATS CRM logo and links for Home, Project Applications, User Applications, Projects, UNIX Users, Host Accesses, Employers, All, My RATS Account, Help, and Logout. Below the navigation bar is a welcome message: "Welcome to RATS CRM".

The dashboard is divided into several sections:

- Check UNIX User Status:** A form with a dropdown menu set to "jameson" and a "Check" button. Below the form, it displays: "User: sydh", "Full Name: Ms. Sydney Herman", "User Status: ✘ Disabled", and "Active Accesses:".
- Upcoming Downtimes:** A table showing downtime entries. It includes a search bar, "Showing 1 to 2 of 2 entries", and pagination controls. The table has columns for ID, System, Starts At (EST/EDT), and Duration (Hours).

ID	System	Starts At (EST/EDT)	Duration (Hours)
19317	ace	2025-04-18 12:08:00 -0400	48.00
19318	frontier	2025-04-18 12:08:00 -0400	48.00
- My Public Staff Profile:** A section showing "Last Updated: Never" and a link to "View My Public Staff Profile".
- My RATS Account:** A section showing account details: "RATS Username: allmon", "Name: aroswift (Mr. Aaron Barlow)", "Email: 14220@fake.ccs.ornl.gov", "RATS Roles: 6", and "RATS API Keys: 0".
- Projects Ending Soon:** A section titled "Terminating in next 30 days" with a search bar and "Showing 1 to 10 of 102 entries". It contains a table with columns for Project ID, Description, Project PI, PI Institution, Organization, and Security Enclave.

Project ID	Description	Project PI	PI Institution	Organization	Security Enclave
TST001	Science Project	Employer 204	OLCF	Moderate	
TST002	Science Project	Employer 16	OLCF	Moderate	
TST003	Science Project	Employer 3558	OLCF	Moderate	
TST004	Science Project	Employer 4269	OLCF	Moderate	
TST005	Science Project	Employer 143	OLCF	Moderate	

# RATS CRM: Project-Centric Approach

1. Simplifies management
2. Definitive configuration source
3. Enables life-cycle automation

The screenshot displays the RATS CRM interface. At the top, a navigation bar includes the RATS CRM logo and links for Home, Project Applications, User Applications, Projects (highlighted), UNIX Users, Host Accesses, Employers, and All. Below the navigation bar, the main content area is titled 'Projects' and shows details for project 'TST001', including its OLCF status, security level (Moderate), and program (OLCF Director's Discretionary Program). A left sidebar lists various project-related sections such as General, Subprojects, Project Applications, Mirrors, Status, Host Accesses, Resources, Allocations, Fundings, Points of Contact, IP Allow Lists, Quantum Backends, Custom Fields, UNIX Users, Scheduler Configurations, Automation Users, Sudo Rules, UNIX Groups, Directories, Primary / Default Filesystems, and Auto Email Settings. The main content area is divided into sections: 'Science Project' (with details like 'Enabled until Apr 22, 2025' and 'Part of the OLCF organization'), 'Principal Investigator' (Dr. Gali Keplier), 'Classifications' (Research Area: Astrophysics, Science Category: Physics), 'Allocation Programs' (Current: OLCF DIRECTOR'S DISCRETIONARY PROGRAM, All: DD 2023), and 'History'. A right sidebar contains a comprehensive list of system settings and controls, including OLCF Applications, Auditing, End-user Controls, Public Web Profiles, and App Configuration.

# RATS CRM: From Proposal to Access

## 1. Proposal Submission

- Researcher submits proposal via MyOLCF

## 2. Review & Approval

- Admin reviews and applies policy

## 3. Automated Setup

### 1. Project-level setup

- Scheduler configuration & filesystem creation
- Sub-projects enable delegation and subdivision

### 2. User-level setup

- UNIX user & group creation, filesystem creation, identity access sync, myOLCF access
- Cascaded resource & filesystem access

## NFS Home Areas

ID	Path	Policy/Template	Owner/UID	Group/GID	User	Project	Permissions	Quota	State
65665	<a href="#">/fake/direct</a> <a href="#">ory/pa</a> <a href="#">th</a>	OLCF Moderate Project Home (nccs_mod_filer_proj) project home area	root / 0	gen110 / 27121	--	GEN110	0770	50	RECONCILED

## GPFS Filesystems

ID	Path	Policy/Template	Owner/UID	Group/GID	User	Project	Permissions	Quota	State
54190	<a href="#">/gpfs/alpine2/ge</a> <a href="#">n110</a>	Alpine2	root / 0	gen110 / 27121	--	GEN110	2755		PENDING
54191	<a href="#">/gpfs/alpine2/ge</a> <a href="#">n110/scratch</a>	Alpine2	root / 0	gen110 / 27121	--	GEN110	2750		PENDING
54193	<a href="#">/gpfs/alpine2/ge</a> <a href="#">n110/proj-shared</a> symlink: <a href="#">/gpfs/alpine2/pr</a> <a href="#">oj-shared/gen110</a>	Alpine2	root / 0	gen110 / 27121	--	GEN110	2770		PENDING
54194	<a href="#">/gpfs/alpine2/ge</a> <a href="#">n110/world-</a> <a href="#">shared</a> symlink: <a href="#">/gpfs/alpine2/wo</a> <a href="#">rld-</a> <a href="#">shared/gen110</a>	Alpine2	root / 0	gen110 / 27121	--	GEN110	2775		PENDING

RATS CRM: directories with anonymized data

# RATS CRM: A Closer Look at Scheduler Configurations

## 1. Centralized policy control for each HPC system:

- Queues / partitions
- Job size limits & default wall times
- QOS policies

## 2. Defined once, applied everywhere:

- System-wide defaults
- Project and user specific overrides
- Supports cascading rules by project, group, or user

## 3. Simplifies multi-scheduler environments:

- Abstracts SLURM, LSF, KUBE, MOAB config differences

### Defaults

ID	↑↓	Context	↑↓	Granularity	↑↓	Target	↑↓	Perpetual?	↑↓	Precedence
1915		Resource: Summit		Per User		User: All Users		✓ Yes		50 / 100
310		Resource: Summit		Per Project		Project: All Projects		✓ Yes		0 / 100
311		Resource: Summit		Per User		User: All Users		✓ Yes		0 / 100

### Overallocation Auto-Penalties

Showing 1 to 10 of 303 entries

ID	↑↓	Context	↑↓	Granularity	↑↓	Target	↑↓	Perpetual?	↑↓	Precedence
2048		Resource: Summit		Per Project		Project: TST001		✓ Yes		75 / 100
5632		Resource: Summit		Per Project		Project: TST002		✓ Yes		75 / 100
2052		Resource: Summit		Per Project		Project: TST003RSCH		✓ Yes		75 / 100
5380		Resource: Summit		Per Project		Project: TST004		✓ Yes		75 / 100

*RATS CRM: HPC scheduler configurations with anonymized data*

# RATS CRM: A Closer Look at Scheduler Configurations Cont.

## RATS CRM: Individual Scheduler Configuration

SLURM Scheduler Configuration '1077' on Dtn

[← Back](#) [Edit](#)

### Basics

ID: 1077

Config Type: default

Context: Resource: Dtn

Granularity: per\_project

Target: Project: All Projects

Precedence: 50 / 100

Status: ✔ Enabled

Valid From: 2019-09-10 16:10:00 -0400

Valid Until:

Description:

### Constraints

Name	Value	Description
minsize	1	Minimum jobsite constraint for this configuration
maxsize	4	Maximum jobsite constraint for this configuration

### Priorities & Limits

Name	Value	Description
Priority	0	Scheduling priority for eligible batch jobs per this scheduler scope.
MaxWallDurationPerJob	24	Maximum allowable walltime hours for running batch jobs per this scheduler scope.

## Equivalent Scheduler Configuration via API

```
"config_type": "default",
"resource": "dtn",
"source_id": 1077,
"description": "",
"precedence": 50,
"primary_scope": {
  "id": 52,
  "type": "Resource",
  "name": "Dtn"
},
"secondary_scope": {
  "id": 9,
  "type": "SchedulerCredential",
  "name": "All Projects"
},
"granularity": "per_project",
"constraints": [
  {
    "type": "minsize",
```

# Managing HPC Systems via API: Scheduler Configurations

## Retrieving Scheduler Configuration Data

### Request

```
GET /api/scheduler_configurations
```

### Response

```
[{ ...,
  "attributes": {
    "config_type": "default",
    "resource": "frontier",
    "precedence": 50,
    "primary_scope": { ... },
    ...
  }, ...
}]
```

## HPC Systems Enforcement

```
# Assume API response parsing above
for entry in "${config_lines[@]}"; do
  read -r part min_n max_n wall_h <<< "$entry"
  for host in "${SLURM_HOSTS[@]}"; do
    ssh admin@"$host" "sacctmgr --immediate update
      partition name=$part \
      set MinNodes=$min_n MaxNodes=$max_n \
      MaxWall=${wall_h}:00:00 \
      || sacctmgr --immediate add partition name=$part \
      default=NO target=ALL MinNodes=$min_n \
      MaxNodes=$max_n MaxWall=${wall_h}:00:00"
    ...
  done
done
```

# Managing HPC Systems via API: UNIX Groups

## Retrieving UNIX Group Data

### Request

```
GET /api/groups?filter['system']=frontier
```

### Response

```
{  
  "data": {  
    "type": "groups",  
    "id": 1,  
    "attributes": {  
      "name": "testgroup",  
      "gid": 10000,  
      "organization": "olcf",  
      "security_enclave": "moderate"  
    }, ...  
  }  
}
```

## HPC Systems Enforcement

```
#!/bin/bash  
# Triggered via cronjob every 30 minutes:  
# */30 * * * * /opt/scripts/group_enforcement.sh  
  
groups_json=$(curl -s -H "Authorization: Bearer  
$API_TOKEN" "$BASE_URL")  
  
echo "$groups_json" | jq -r '.[] | .data.attributes | "\(.name)  
\(.gid)'"  
  
while read -r group gid; do  
  for system in "${HPE_SYSTEMS[@]}; do  
    ssh admin@"$system" "sudo groupadd -g $gid $group"  
  done  
done
```

# RATS Report: HPC Analytics & Reporting

- **Key capabilities:**
  1. Extracts, transforms, and loads (ETL) HPC data
  2. Monitoring of compute resource consumption
  3. Allocation burn-down analysis
  4. Custom queries for job and storage analytics
  5. Aid in auditing
- 4 API endpoints with filtering to disseminate information

The screenshot displays the RATS Report homepage interface. At the top, there is a navigation bar with icons for 'RATS REPORT', 'Compute Usage', 'Filesystems', and 'Job Search'. On the right side of the navigation bar, there are links for 'Help' and a user profile 'aroswift'. Below the navigation bar is a horizontal menu with tabs for 'Resources', 'Resources/Programs', 'Resources/Users', 'Programs', 'Programs/Projects', 'Projects', 'Project Groups', 'Science', 'Allocations', and 'Custom Query'. The main content area is divided into four panels:

- By Resource:** Explore utilization and availability stats per resource including Summit, Titan, Eos, Rhea, Cumulus, and others.
  - Resources - Overall Utilization and Availability
  - Resources/Programs - Usage Breakdown by Program
  - Resources/Users - Usage Breakdown by Project and User
- By Program:** Compare burn rates and usage breakdowns for all allocation programs including INCITE, ALCC, DD, ECP, and Early Science.
  - Programs - Burn Rates
  - Programs/Projects - Usage Breakdown by Project
- By Project:** Search for project allocations by name, PI, year, etc. and see burn rates and daily usage.
  - Projects - Burn Rates and Daily Usage
  - Project Groups - Usage and Utilization across Resources and Allocations
- Custom Queries:** Get GPU usage and capability stats for any combination of user, project, program, cycle, and resource.
  - Custom Query

# MyOLCF: Public Self-Service Application

- Publicly available application that extends management capabilities and provides insights into available resources for users
  - [my.olcf.ornl.gov](http://my.olcf.ornl.gov)
- Some key features:
  - Apply for and renew projects and accounts on HPC systems
  - Check the status of their applications
  - Monitor their submitted issues
  - Allocation usage monitoring
  - Compute usage report generation
  - Schedule office hours for help

The screenshot displays the MyOLCF web application interface. At the top, the Oak Ridge National Laboratory and Leadership Computing Facility logos are visible, along with the 'myOLCF' branding. The user is logged in as 'aroswift' with the email 'avery@fake.ccs.ornl.gov'. The main content area shows the 'Project Profile' for 'TST001: Science Project'. The profile includes a 'General' section with the following details: Project ID: TST001, Name: Science Project, Organization: OLCF - Oak Ridge Leadership Computing Facility, Security Enclave: Moderate, and Research Summary: --. Below this is a 'Points of Contact' section listing the Account manager as Sarah Swift and the Principal Investigator as Aaron Barlow. A left-hand navigation menu is visible, containing sections for 'MY PROJECTS' (with a dropdown for 'TST001'), 'OVERVIEW' (Project Profile, Renew My Membership), 'USERS', 'ALLOCATIONS', 'SETTINGS', 'ANALYTICS' (Project Usage, Compute Jobs, Filesystem Usage, Aggregated Usage), and 'OFFICE HOURS'. A right-hand user menu is also present, offering options like 'MY PROFILE', 'FOR MY APPROVAL', 'MY ACCOUNT APPLICATIONS', 'NEW PROJECT APPLICATION', 'JOIN ANOTHER PROJECT', 'TICKETS', 'FAQ', and 'LOG OUT'. The footer contains logos for the U.S. Department of Energy, Office of Science, and Oak Ridge National Laboratory, along with contact information and a Facebook link.

# OLCF Acknowledgement

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# Questions?

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