



# **Engineered Resilient Systems Architecture**

**18th Annual NDIA Systems Engineering Conference  
October 28, 2015**

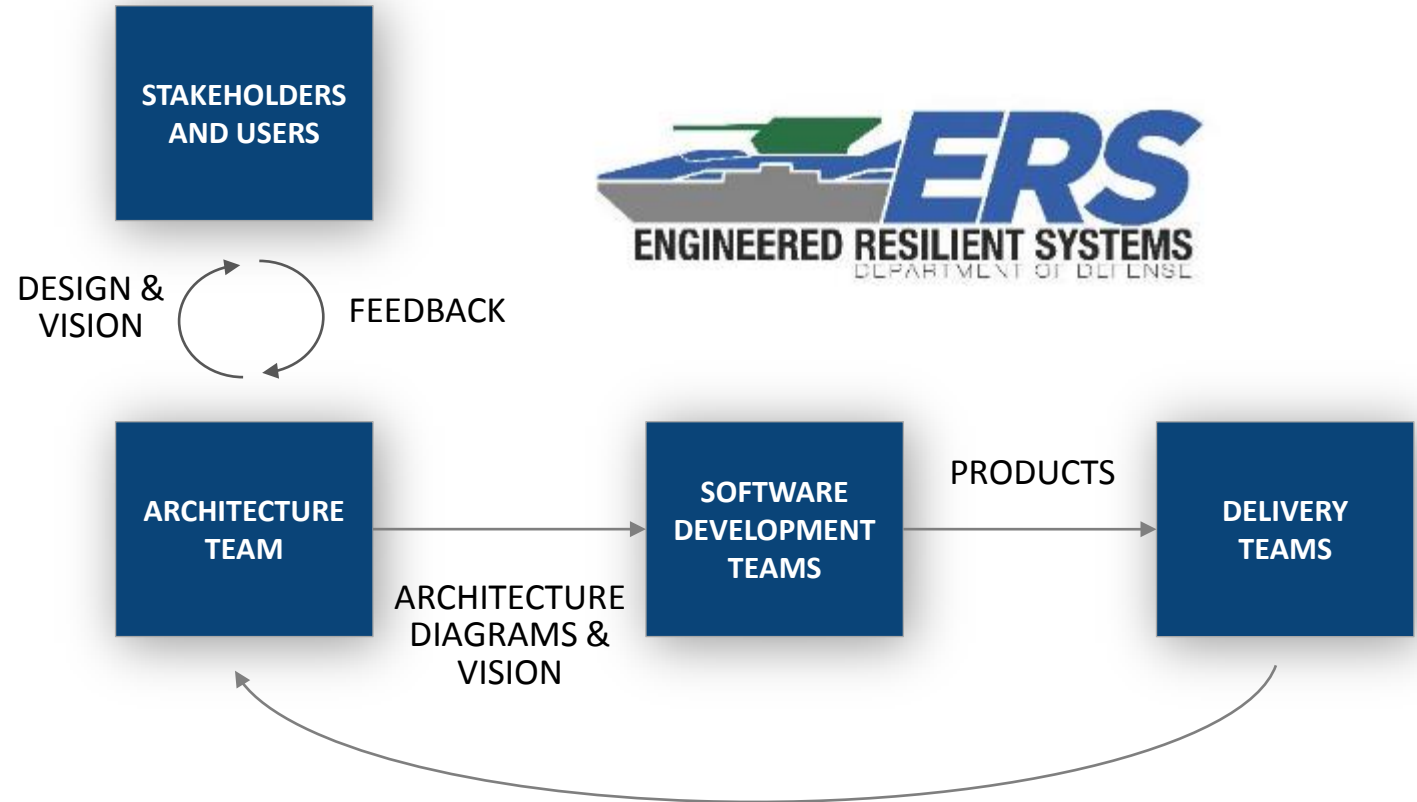
**Dr. Cary D. Butler, ERS Architecture Lead, Technical Director, ITL  
Dr. David C. Stuart, Associate Technical Director, ITL (Presenter)  
US Army Engineer Research and Development Center (ERDC)**



# ERS Architecture – Integrating Capabilities



- Provide a cohesive, integrating capability for ERS tools, technologies and products
- Develop reference architecture
- Promote reuse and common infrastructure
- Develop guidance and standards
- Work closely with application and development teams



- Architecture artifacts evolve and are refined over time
- Development cycles are aligned with product deliveries



# ERS User Groups

## STRATEGIC PLANNERS

- Satisfy national security objectives

## OPERATING COMMANDS

- Analyze operational situation
- Identify capability gaps & strengths

## PROGRAM MANAGEMENT

- Program Execution
- Delivered on time within cost
- Meet warfighters' requirements

## DOD SYSTEM DESIGNERS

- Identify designs that meet performance & mission objectives

## DOD T&E

- Identifies early knowledge of developmental & operational issues

## INDUSTRY

- Identify design alternatives
- Proposal devt & production
- Better understanding of requirements



## DOD M&S



## DOD HPC



## ERS ANALYTICS



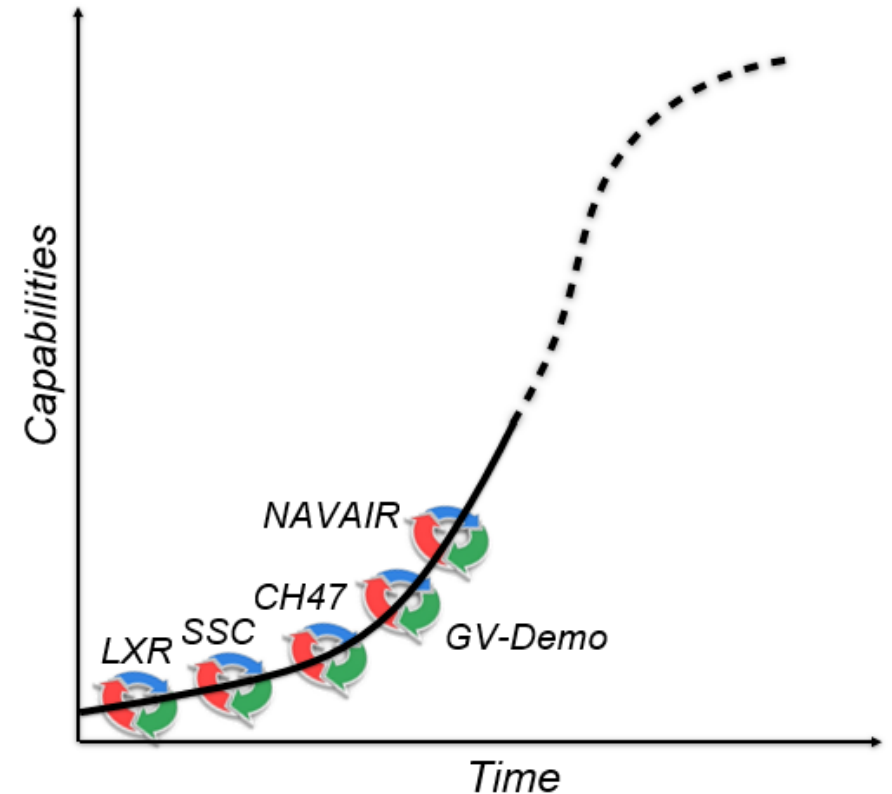


# Architecture Drivers

- Improve impact of ERS through **early, continuous delivery of products**
- Focus: **Building early user acceptance and adding capabilities as needed/wanted**
- Enable **“Open” computing framework to support cross-community (DoD-Industry)**
- Apply **advanced computing methods to improve accuracy, depth, and breadth of tradespace studies**

**Integration with Industry is key to success.  
Participation in Architecture Working Group  
kicks off: Nov 2015**

*Working products are the primary measure of progress.*



*Represents a cycle in development*

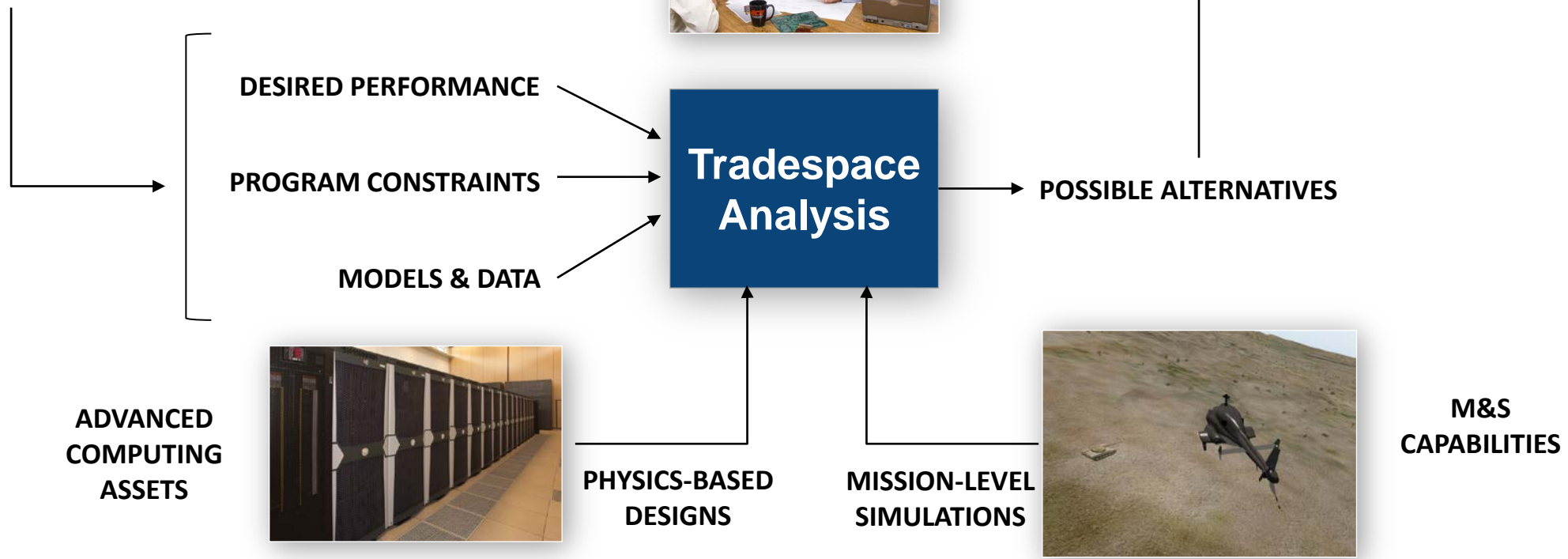


# Tradespace Analysis

**Advanced Tradespace Analysis** tools are at the core of the ERS capability.

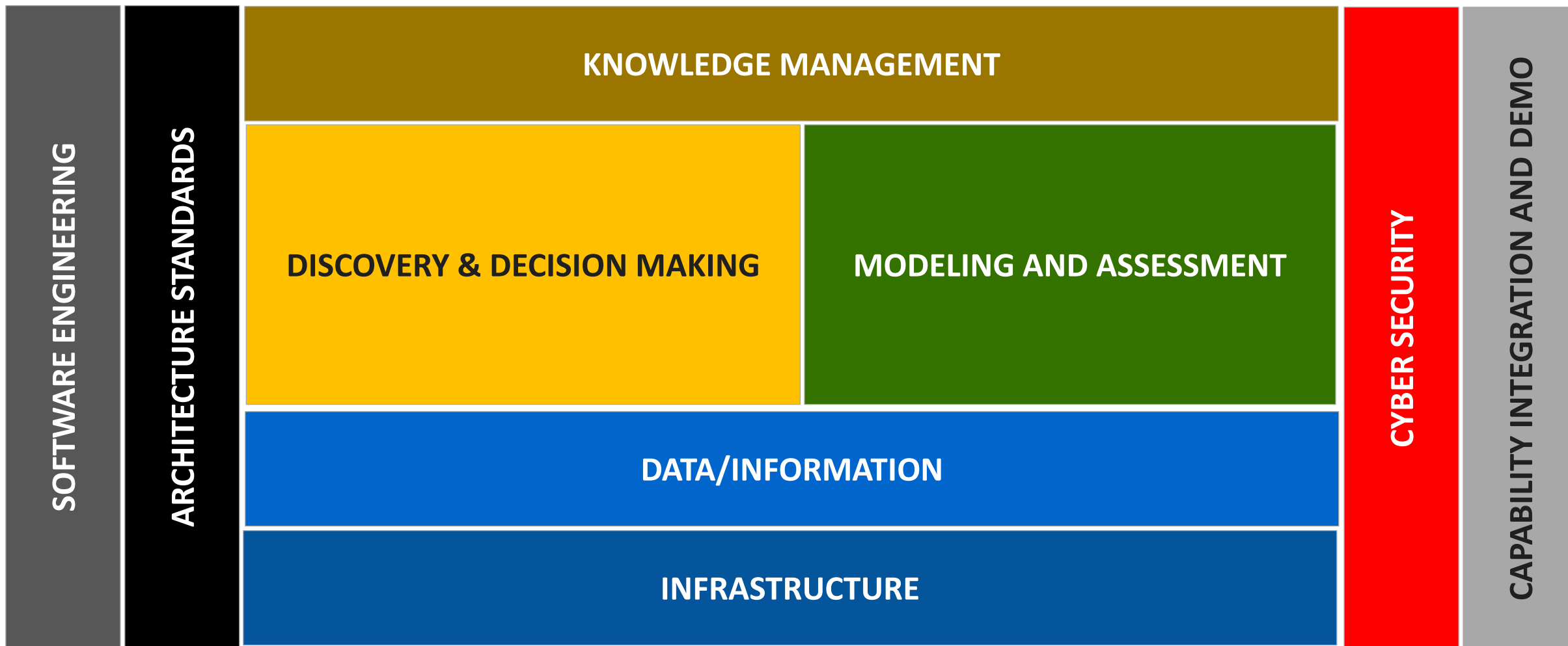
*ERS focuses on improving decision-making by integrating computational resources that increase accuracy and depth of analysis.*

*Decision-makers refine the system by trading cost, performance, schedule, and risk.*





# ERS Building Blocks (Reference Architecture)





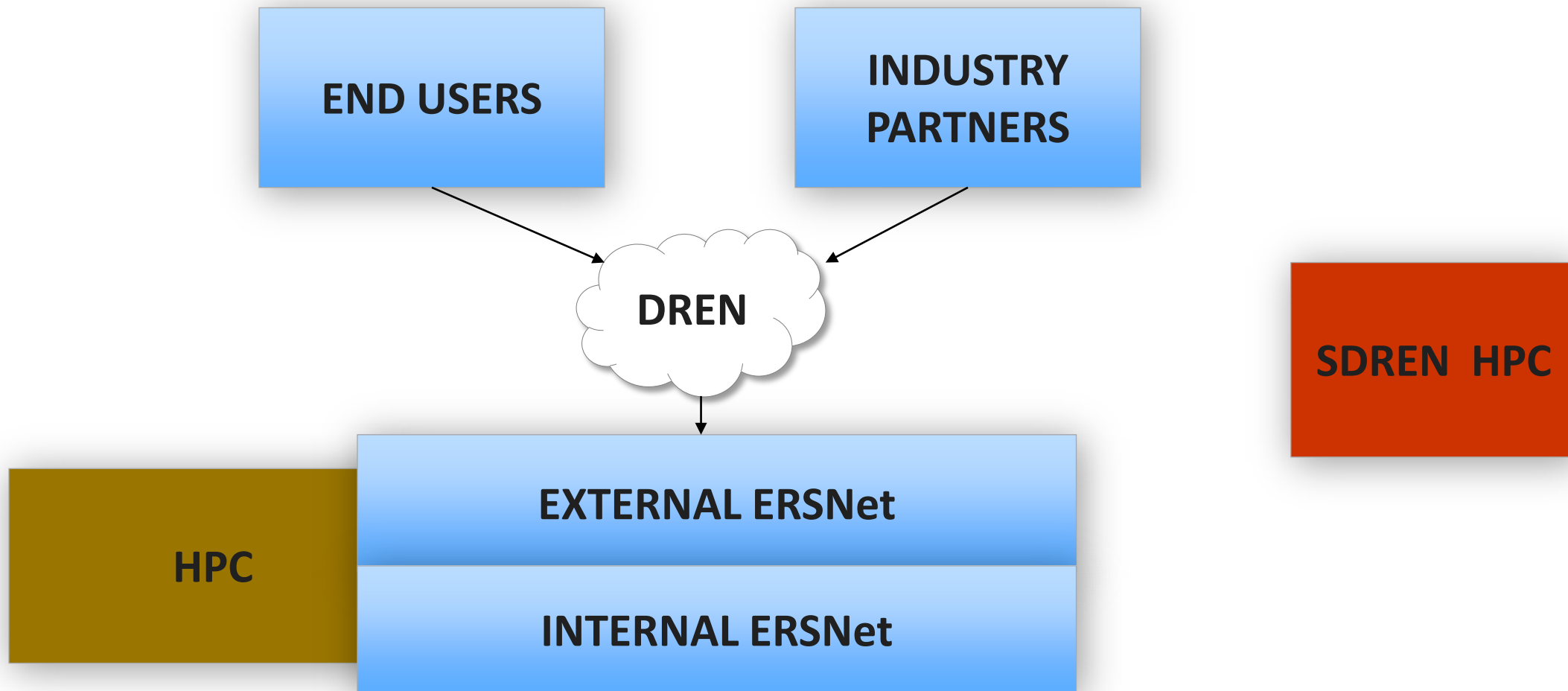
# ERS Open Architecture

- Modular back-end in Node.js using REST services.
- Project data structures in easily read MongoDB JSON.
- Front-end tools added through AngularJS directives.
- Projects and Data accessible through REST API.
- High performance low-level API for tradespaces.
- “R” Analytics tool allows for custom analysis.
- SAML-based 2 factor identity services for federated user management





# ERS Infrastructure



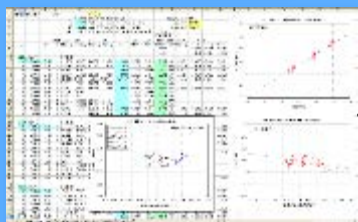




# TradeStudio Processes

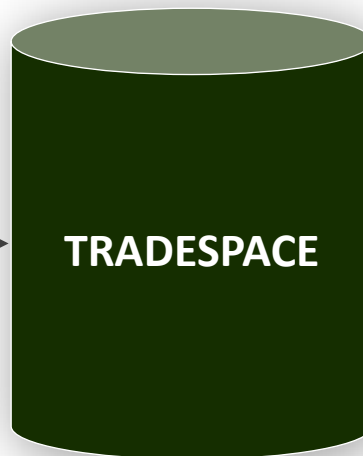
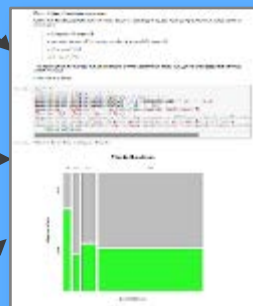
## MODELING PHASE

### TRADESPACE CREATION



Jupyter Notebooks

- Existing Codes
- Domain models
- Spreadsheet
- Python/R Wrappers



TRADESPACE

- HDFS Format
- Metadata included
- Stats
- Low-level API (c/c++)

## ANALYSIS PHASE

### TRADESPACE ANALYSIS



#### Open Architecture

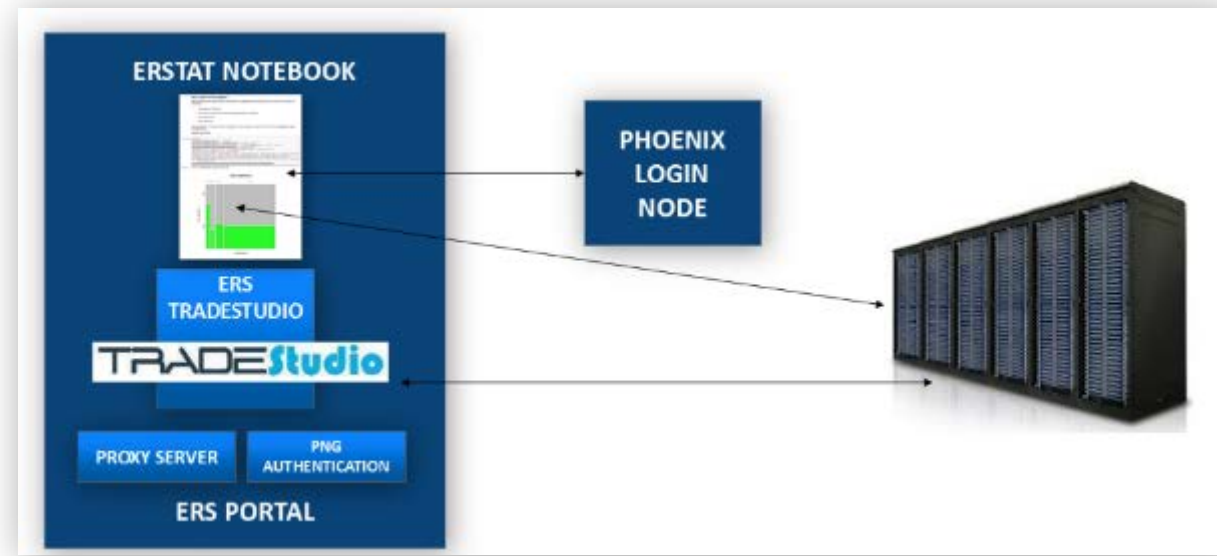
- Tradespace API (REST)
- GUI Modules
- REST Services
- R. Modules



# ERS Tradespace Assembly Toolkit (ERSTAT)



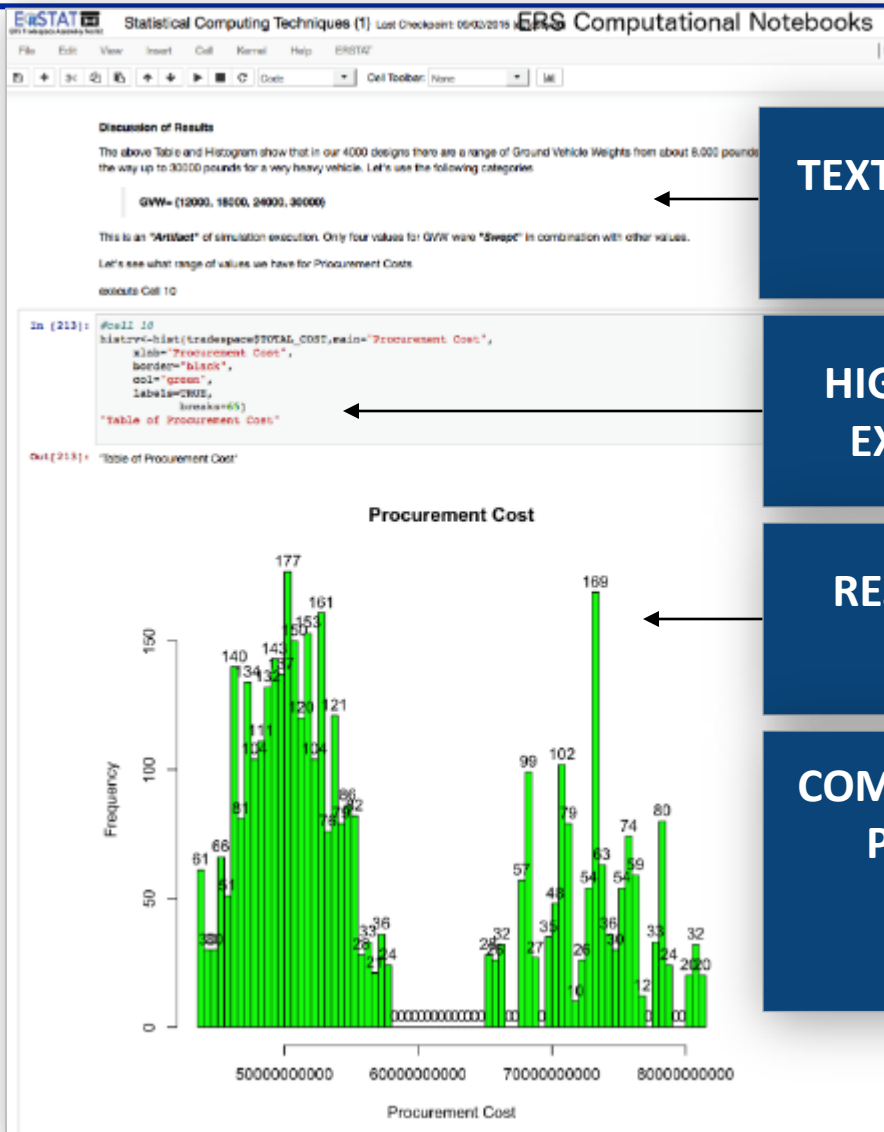
- Introduce DoD Conceptual Design Teams to the Cloud Computing Environment (CCE)/HC
- Introduce DoD Conceptual Design Teams to R Language
- Enhance Collaboration
- Gather and distribute cross-cutting functionality
- Examine, profile and improve model assembly pipelines



*ERSTAT is a computational environment that connects legacy M&S to the ERS Workflow*



# Computational Notebooks



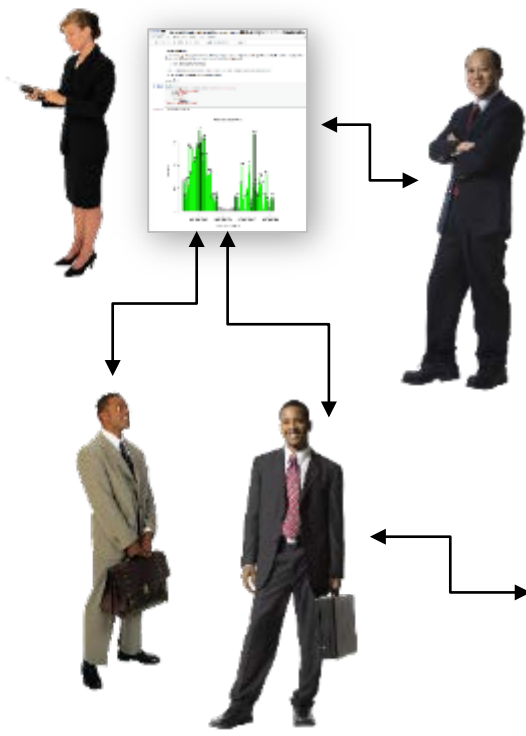
**TEXT, DIAGRAMS, EQUATIONS EXPLANATIONS**

**HIGH-LEVEL CODE DIRECTLY EXECUTABLE ON ERS HPC**

**RESULTS, TABLES, GRAPHS, STATISTICS**

**COMPUTATIONAL NOTEBOOK: PIPELINE OF ACTIVITIES EASE OF USE EASILY SHARED**

**NOTEBOOKS ARE DESIGNED TO BE SHARED**



**ERS Common Computing Environment (CCE)**

cloud computing

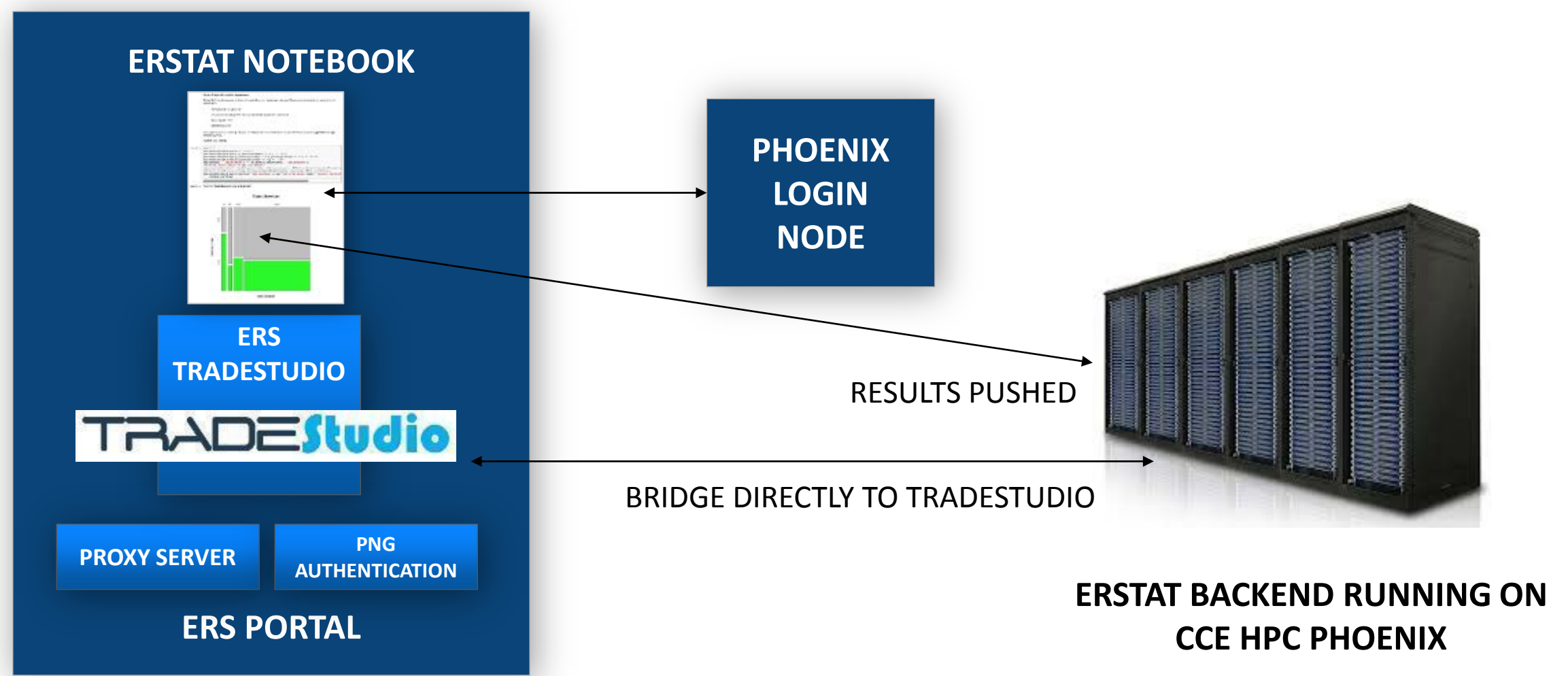


**NOTEBOOKS CAN RUN ON ANY ERS PLATFORM**





# ERSTAT Architecture







# Data Management and Transformation Tools



## Managing data: Projects and Tradespace

### Projects:

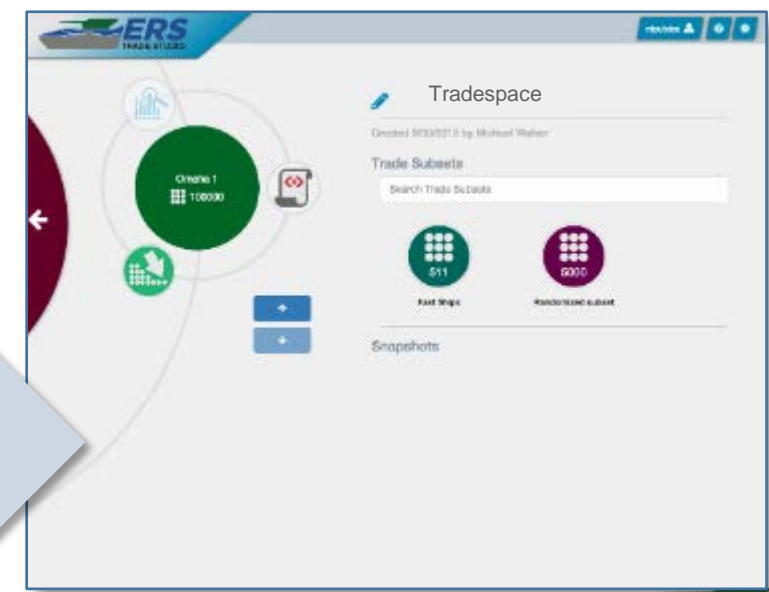
- Top-level data container
- Full security through permissions
- Shared Workspace

### Tradespace:

- Standalone – immutable dataset
- HDF5 format
- Metadata
- Statistics

## Transforming data: Tools

- Appropriate tools surround the tradespace
- Tools can create subsets





# Data Reduction Tools

- Operates on very large tradespaces (up to 10 million designs)
- User selects attributes of interest, conducts scoring process that allows exclusion of designs by attribute value
- Each attribute assigned a weight
- Cumulative score is displayed in real time
- Results saved as a new sub-tradeset with added “score” attribute

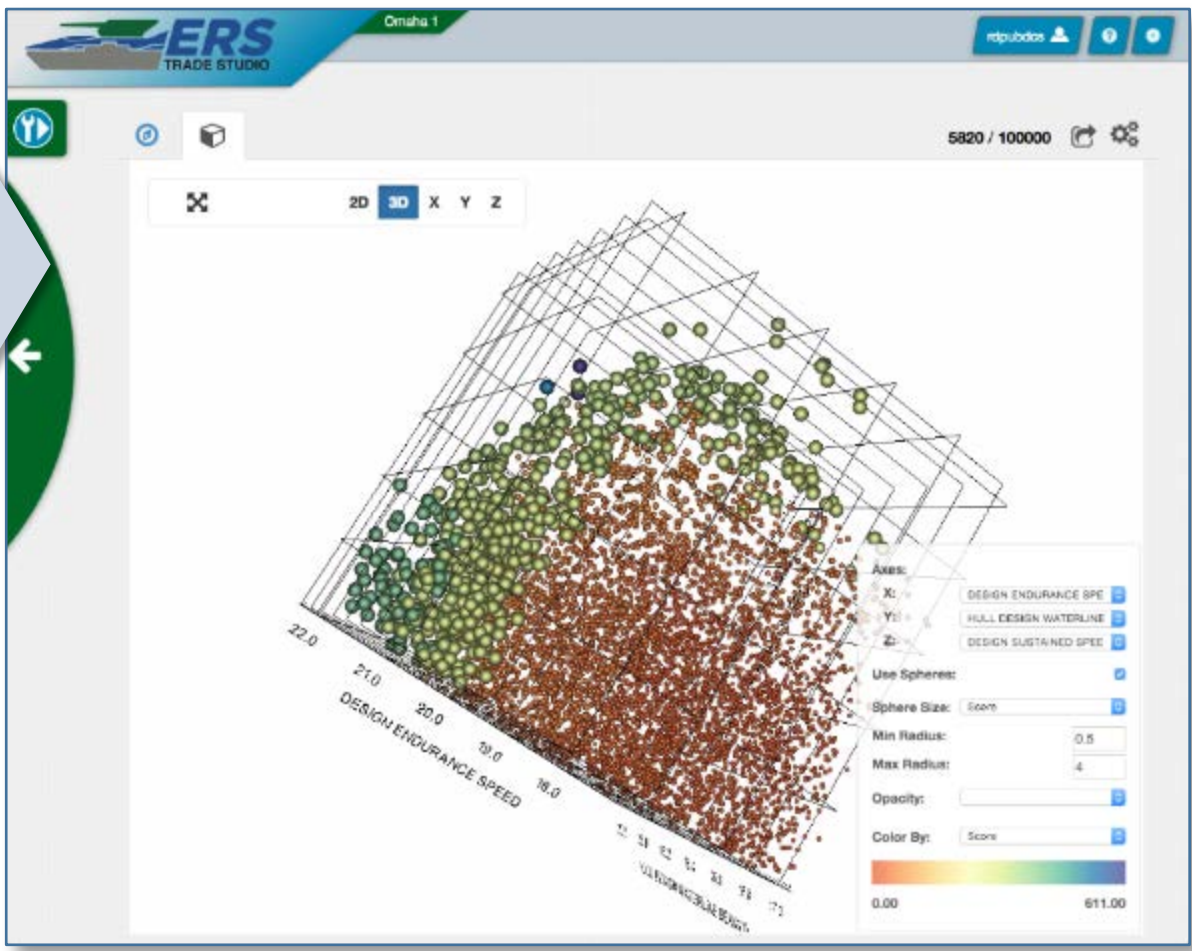




# Data Visualization Tool



- 2D/3D visualizer
- Use color, size and opacity or a fourth attribute

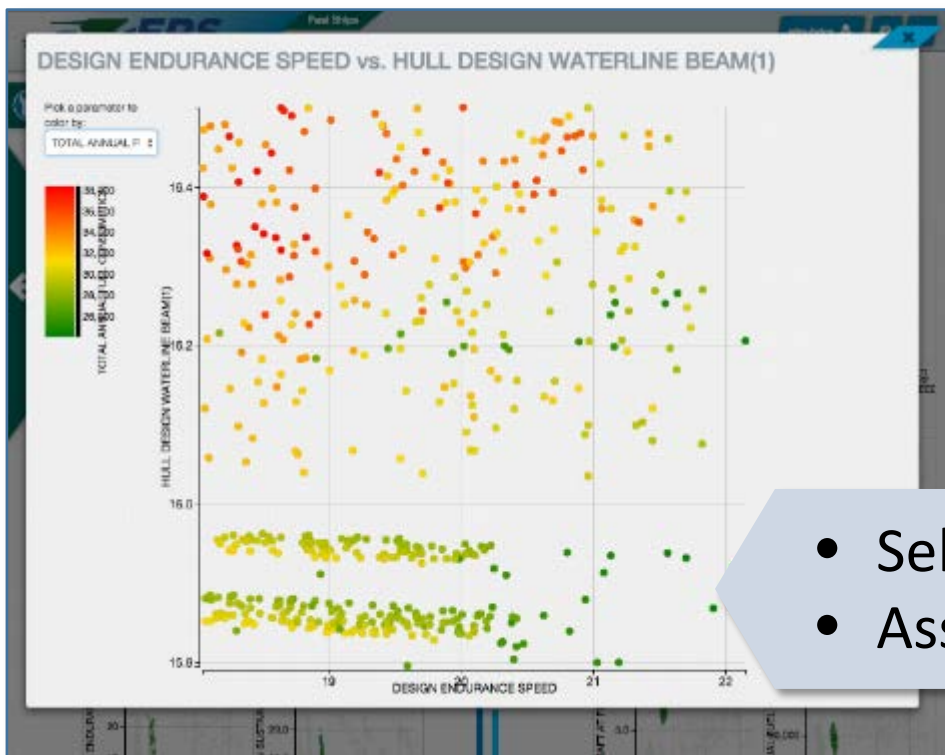






# Data Analysis Tools

- Select attributes to show plot matrix with histograms



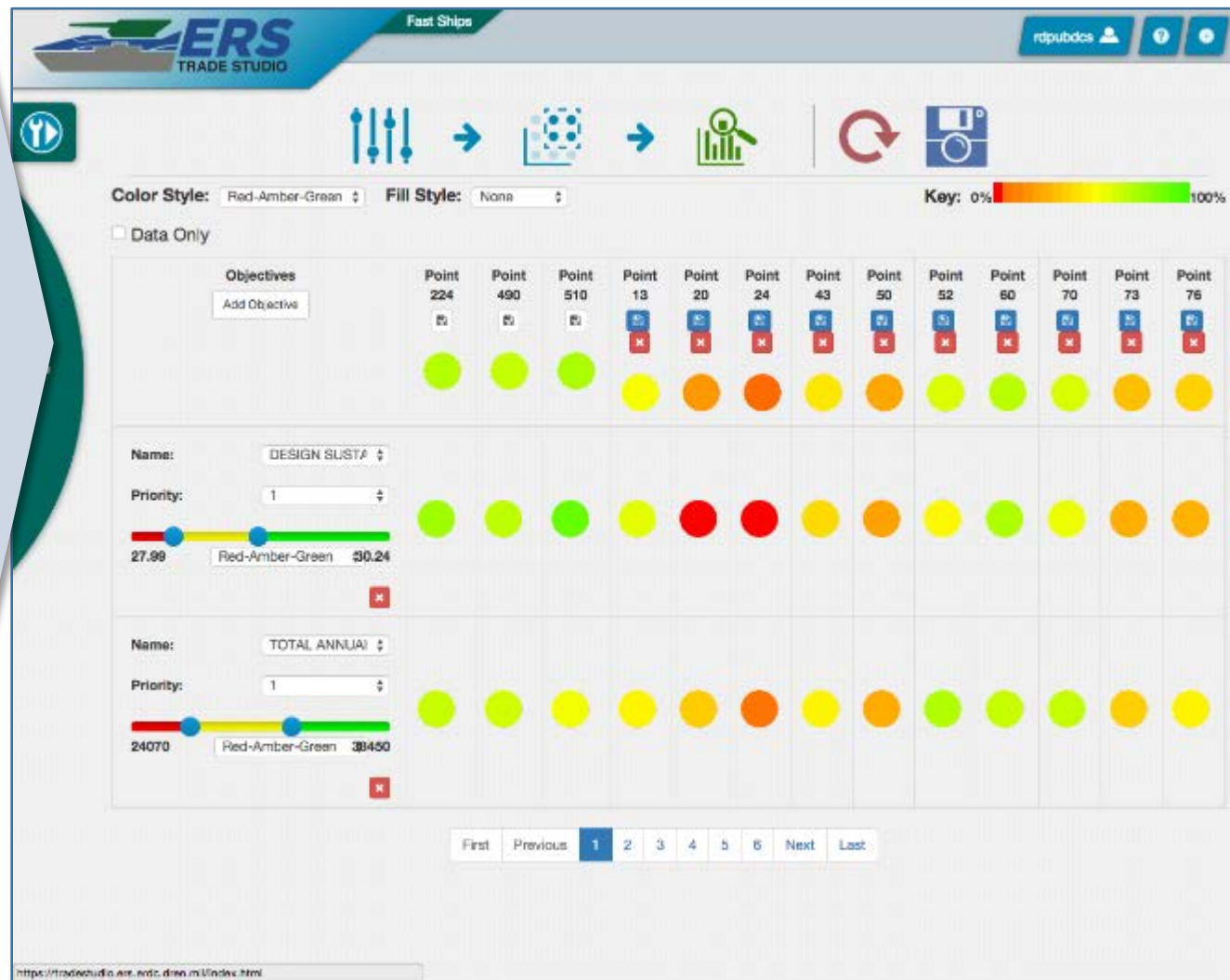
- Select any graph for close-up
- Assign parameter colors





# Data Analysis Tools

- Select “Analyze Points” to run analysis tool
- Select objective attributes
- Change objective values
- Tool calculates score for each design





# “R” Analytics

- “R” script tool allows upload of new, custom analytics
- ERS “R” packages inform what GUI inputs should be
- “R” scripts output plots or new subsets

The screenshot displays the ERS Trade Studio interface. At the top, it says "ERS TRADE STUDIO" and "Omaha 1". On the right, there's a user profile for "rdpubdca". The main area is titled "Scripts" and contains a search bar and an "Upload New Script" button. Below this is a grid of script options, each with a brief description and a "Run" button:

- Density Plot**: Shows density curves in areas with the most points. curveColor is a hex RGB value. curveSize should be a positive number, where 0.5 - 5 is best.
- 2D Histogram**: A histogram of two parameters.
- Binning in 2D with Rug plot**: Produce 2D bins shaded according to the number of points in that region. Additionally, show ticks along the axes to produce a rug. numBins should be 20 or more for best results. loColor and hiColor are hex RGB values.
- Boxplot with Jitter**: Shows a boxplot overlaid on a jitter plot. This is best used when there are few possible x values. loColor and hiColor should be on [0,1] and jitterWidth should be on [0,0.49].
- Quantiles**: Split a scatterplot into any number of sections containing an equal number of points. k\_value is the number of sections into which the plot will be split. curveColor is a hex RGB value for the section division lines.
- Radial Density Plot**: Create a radial density plot where x is angle and y is radius with chosen colors for shading. loColor and hiColor are hex RGB color values.
- Scatterplot with Regression**: Adds a trendline with specified color and size. lineColor is a hex RGB color value. lineSize should be a positive number, where values 0.5 - 8 are best. If curve is "loess", the best fit curve is plotted with no particular prototype function. Otherwise,...
- Shaded Density Plot**: Create a density plot with chosen colors for shading. loColor and hiColor are hex RGB color values.
- Violin Plot**: Create a freform shape to represent the y-values at each discrete x-value. loColor and hiColor are hex RGB values.
- Weighted-Z Tile Plot**: Tile color and size is weighted by value of z-dimension. loColor and hiColor are hex RGB values.
- Test Script**: New Test Script.

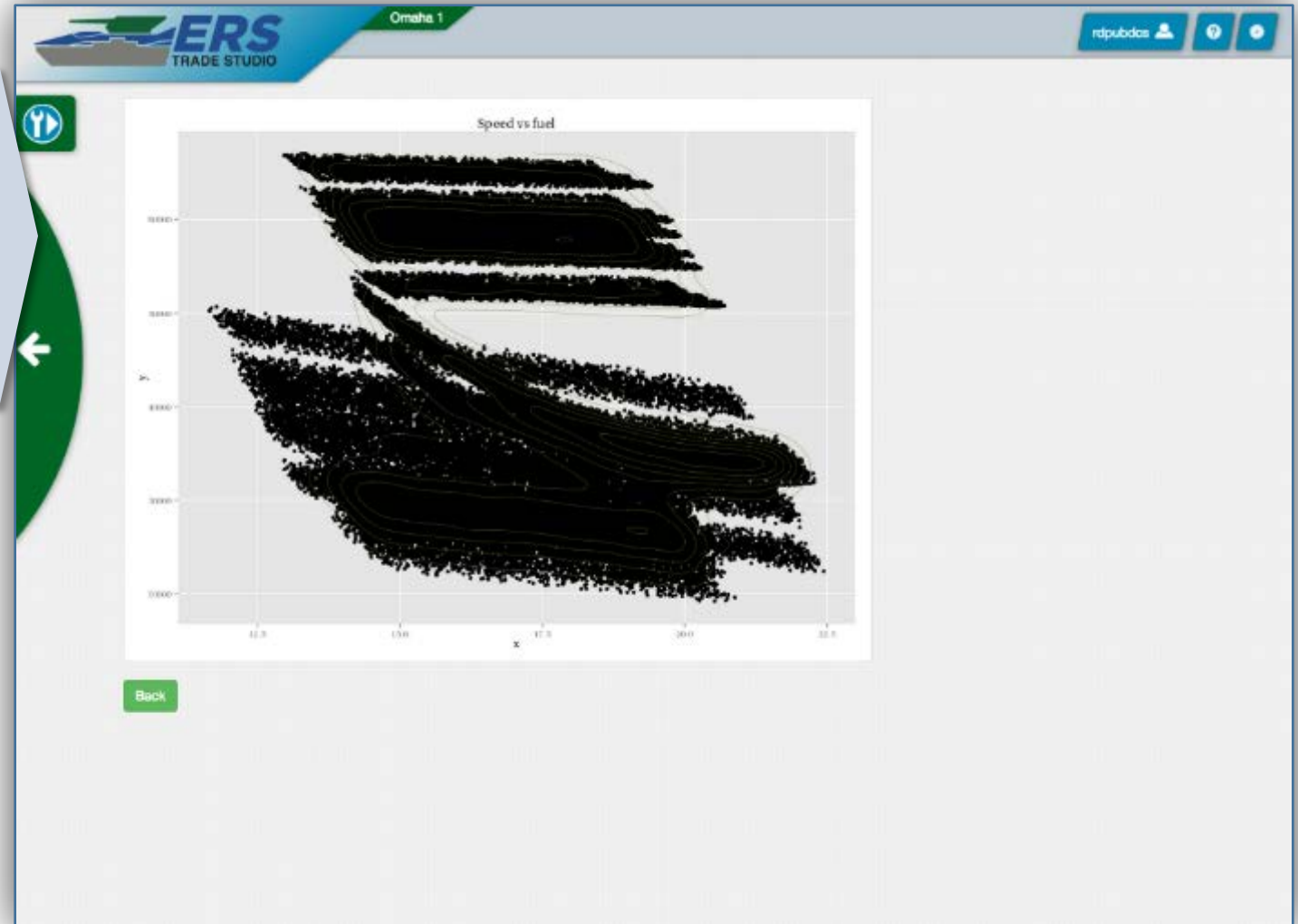
On the right side, the "Results" panel shows a search bar and two "New Run" buttons.





# “R” Analytics

“R” script output is stored in the project relative to the tradeset used to generate it.





David C. Stuart  
[David.c.stuart@erdc.dren.mil](mailto:David.c.stuart@erdc.dren.mil)

# Questions & Answers



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