NATIONAL RECONNAISSANCE OFFICE

An NRO CAAG Survey

NASA Cost and Schedule Symposium
23-25 April 2024

ABOVE AND BEYOND

Cost and Acquisition Assessment Group

VISION

Expanding Analytical Horizons

MISSION

Drive actionable management of risks, issues, and opportunities by applying credible cost/schedule/performance analysis to achieve NRO mission success

KEY ROLES

Cost Estimating & Integrated Program Management

Program Planning, Budget Building, Acquisition Decisions & Design Reviews

NRO ORGANIZATION


Dr. Troy Meink
PRINCIPAL DEPUTY DIRECTOR


Dr. Chris Scolese
DIRECTOR


Maj Gen Chris Povak
DEPUTY DIRECTOR

DIRECTOR

PRINCIPAL DEPUTY DIRECTOR

DEPUTY DIRECTOR

- Advanced Systems & Technology Directorate
- Geospatial Intelligence Systems Acquisition Directorate
- Ground Enterprise Directorate
- Signals Intelligence Systems Acquisition Directorate
- Business Plans & Operations Directorate
- Communications Systems Directorate
- Management Services & Operations Directorate
- Mission Integration Directorate
- Mission Operations Directorate
- Office of Space Launch
- Special Communications Office
- Survivability Assurance Office
- Systems Engineering Directorate

CAAG CUSTOMERS

- LIGHT
- MEDIUM
- HIGH
- CAAG'S HOME

NRO's flat structure enables agility and superior performance

CAAG YEAR IN REVIEW

ESTIMATES

Estimates are a critical component of the budgeting process to establish realistic profiles for program execution. Estimates provide valuable insight into proposal submissions.

- 1 Endorsed ICEs
- 5 ACPs
- 14 Other Estimates

IPM EVENTS

Enterprise IPM ranges from independent assessments to enabling program office development of risk-adjusted baselines that achieve program cost, schedules, technical and performance objectives.

- 5 Independent Assessments
- 12 EVMS Evaluation
- 5 IBRs

ENTERPRISE ANALYSIS

Enterprise engagements deliver CAAG cost and performance analysis innovations to the NRO community. These engagements serve to synchronize work flows and lines of communication that offer enterprise solutions to the NRO.

- 14 Engagements

INFORMATION TECHNOLOGY

Foundational infrastructure, systems, and applications used to process, store, and visualize data supporting CAAG analytics and product.

- 5 Achievements

METHODS

The Annual Methods Plan FY22-23 formalized a CAAG methods process which enables improved CAAG planning, awareness of ongoing initiatives, and status of actions.

- 10 Models
- 5 CERs
- 9 Studies

DATA

The quality of cost estimates is directly related to the quality of Cost, Programmatic, and Technical Data.

- 14 Normalizations

OUTREACH EFFORTS

- 19 Technical Exchanges
- 1 Strategic Exchanges
- 4 Workshops
- 5 Conferences
- 16 Pre-Award Engagements

Cost Integrated Process Team (CIPT)

Established 2000

Multi-day classified engagement – CAAG's cornerstone engagement

- **Led by NRO/BPO-CAAG**
  - Broad government and Industry participation
- **Face-to-face engagements focused on data and methods**
  - *General Session*: Led by NRO CAAG focused on sharing non-proprietary processes, methods & tools
  - *Government-only Session*: Collaboration among peer cost groups
  - *Vendor 1-on-1's*: Direct engagement on program specific cost/technical data, future programs, methods & tools
  - *Tours*: "eyes-on" insight into technologies and processes relevant to NRO acquisitions

IMPACTS

- Obtain vendor insights are folded into CAAG estimates, methods, and acquisition support activities
- Gain Industry perspectives to inform our source selection support to Acquisitions
- Understand of how vendor's market and personnel challenges impact cost and schedule

Strengthening communication, understanding data … pulling the signal out of the noise

CIPT Value

Prime contractors and major subcontractors across the NRO have embraced CIPT

Opportunity to educate their customer and understand the government's views

Opportunity to improve compliance with proposal cost realism criteria

Joint Development Items

→ SWBS: NRO WBS & Mil HDBK-881
→ Data Collection CDRLs: HW & SW
→ NR/REC Cost Definitions

→ Source Selection Estimating Methodologies, RCEs
→ Annual Inflation/Escalation Index

→ ECP Study: Sources and magnitude of contract growth
→ Mission Assurance & Acquisition Complexity Study

Gov't Release to Industry

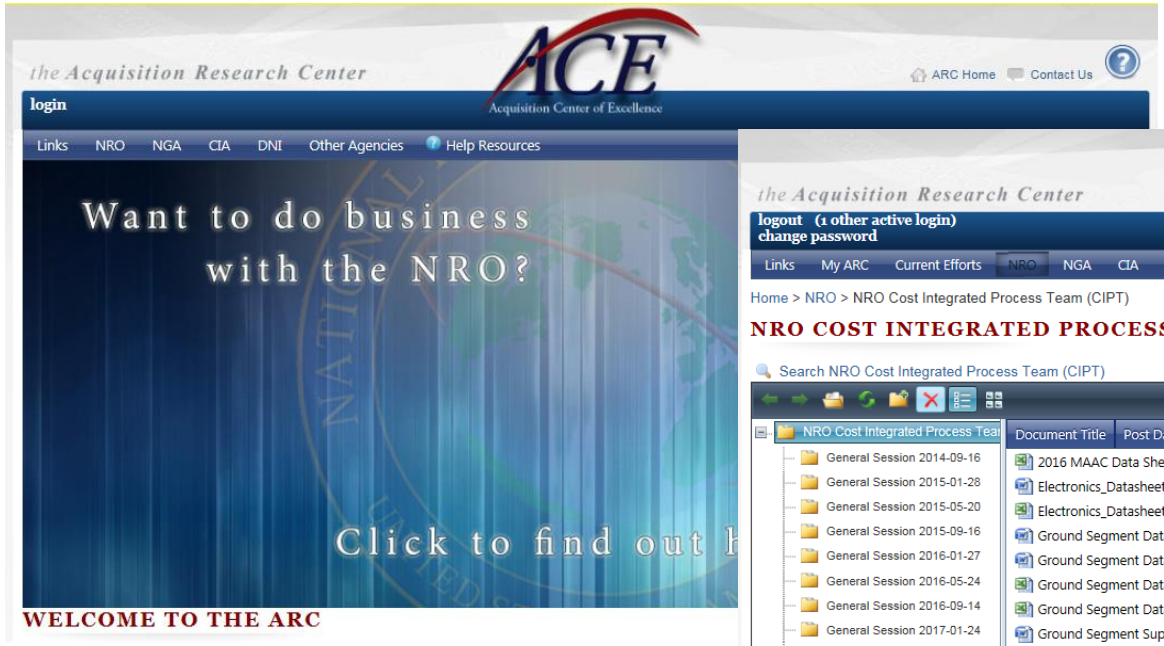
→ 100+ Operational CERs
→ Ground/SW estimating methodologies

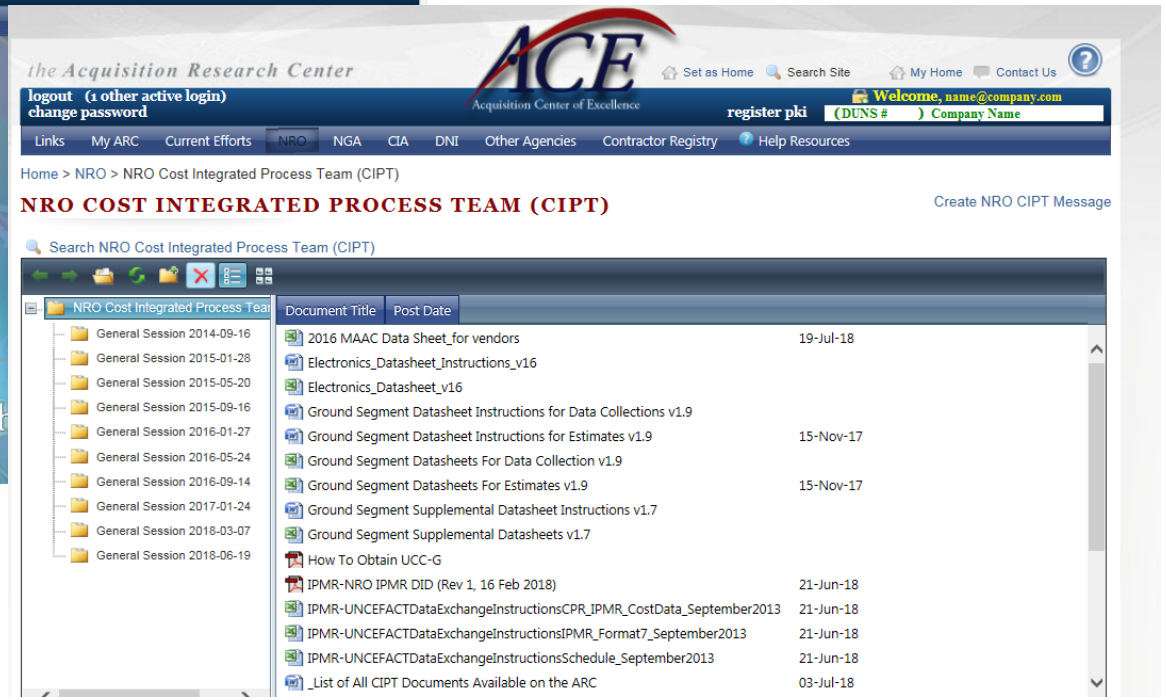
→ Automated CER generation Tools
→ Demonstration Satellite Cost Model
→ Schedule and Phasing Models

→ Program Data Normalizations
→ Data Collection & WBS Mapping Templates
→ IPMDAR Validation Tool

Released Repository

- External facing page on the NRO Acquisition Research Center (ARC) to release models, methods, tools, and other information



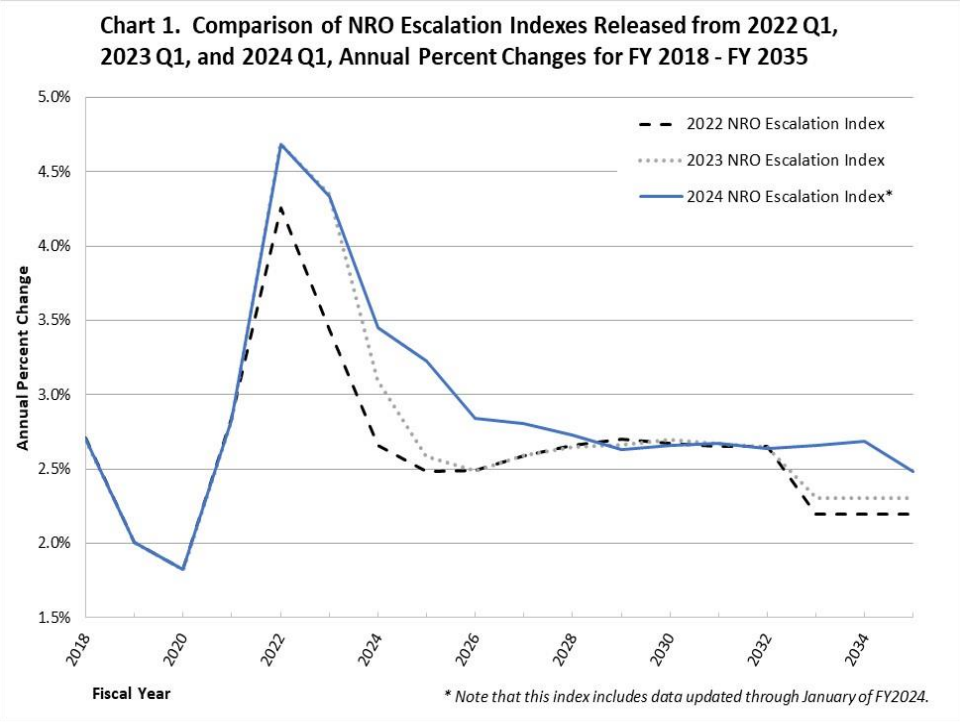


Secure: https://acq.nro.ic.gov/nro/cipt

Unclassified: https://acq.westfields.net/nro/cipt

2024 NRO ESCALATION INDEX

Escalation Indexes from 2023 to 2024



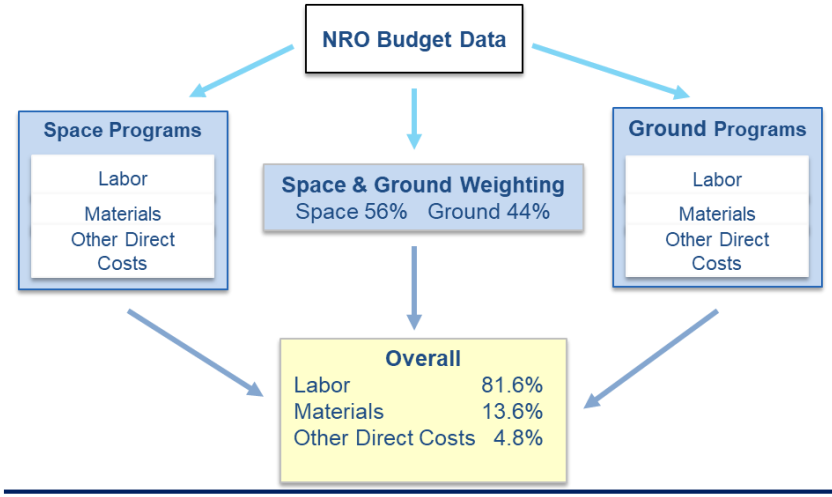
- The NRO Escalation Index was forecast to rise 4.35% in FY 2023, and came in extremely close, at 4.33%.
- The Index is now forecast to rise slightly more in 2024 than forecast one year ago, and also more than was forecast in 2022.
- Looking ahead, the Index is currently forecast to slow at a more gradual pace over the next few years than was forecast last year.

Table 1. Annual Percent Changes from NRO Escalation Indexes for 2022, 2023, and 2024, for Fiscal Years 2022-2030

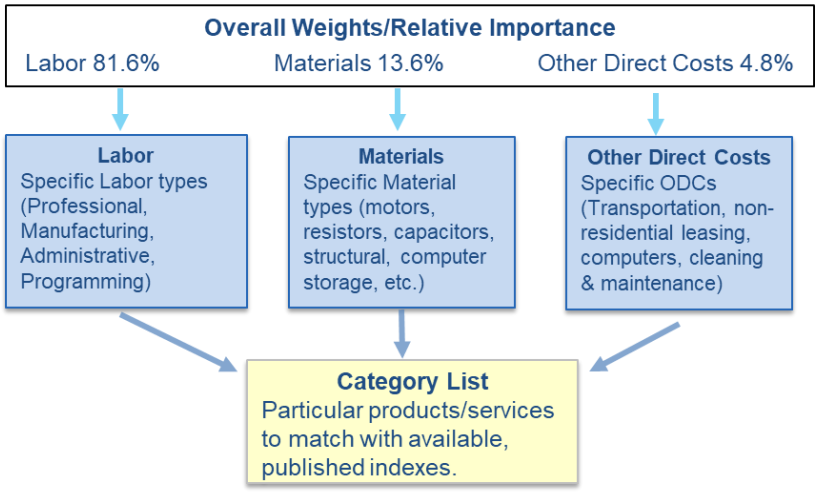
Escalation Index	2022	2023	2024	2025	2026	2027	2028	2029	2030
2022 NRO Escalation Index	4.26%	3.44%	2.66%	2.49%	2.49%	2.59%	2.66%	2.70%	2.68%
2023 NRO Escalation Index	4.69%	4.35%	3.10%	2.59%	2.49%	2.60%	2.65%	2.66%	2.70%
2023 NRO Escalation Index*	**4.68%**	**4.33%**	**3.45%**	**3.23%**	**2.84%**	**2.81%**	**2.73%**	**2.63%**	**2.66%**

Creating the NRO Escalation Index

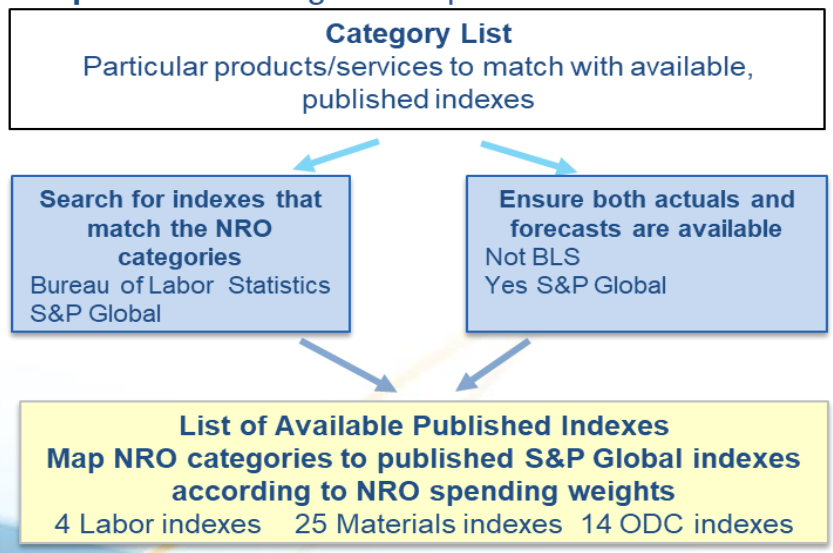
Step 1. Determining what the NRO purchases



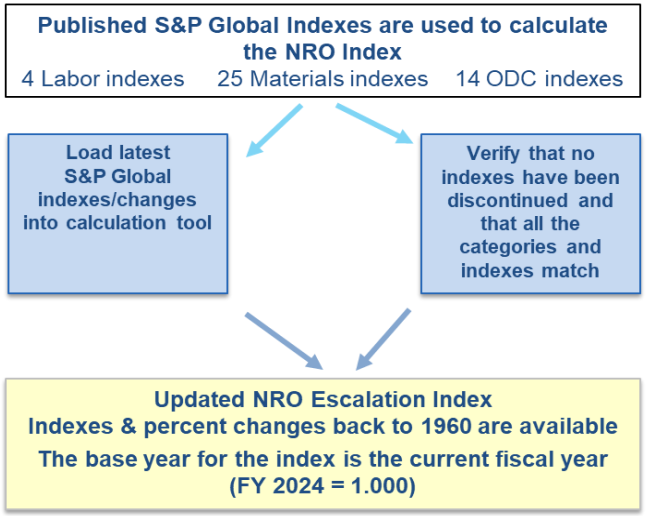
Step 2. Building a weighting structure



Step 3. Match categories to published indexes



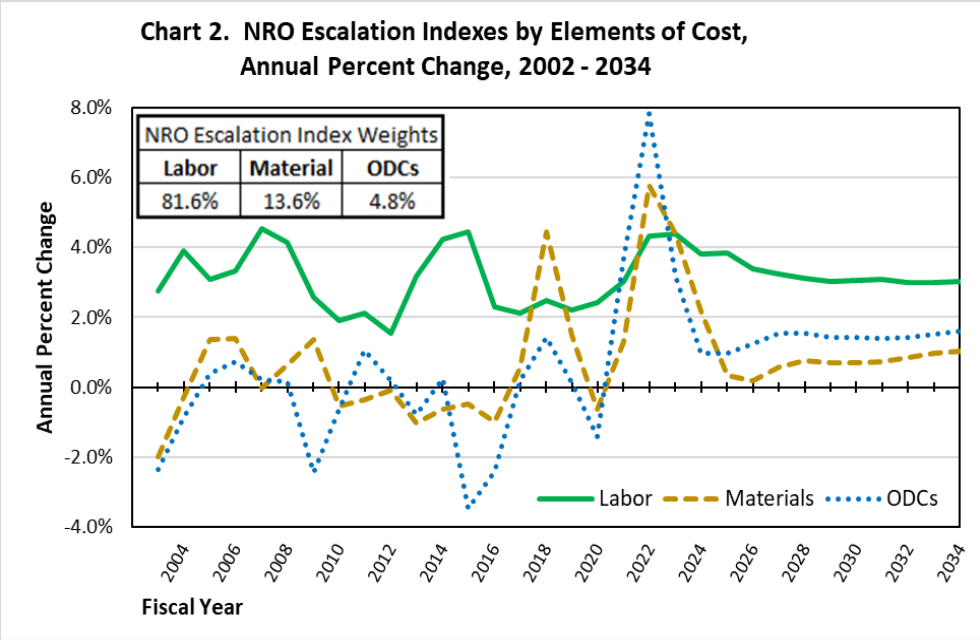
Step 4. Track price movements and calculate index changes



2024 Escalation Index Build Summary

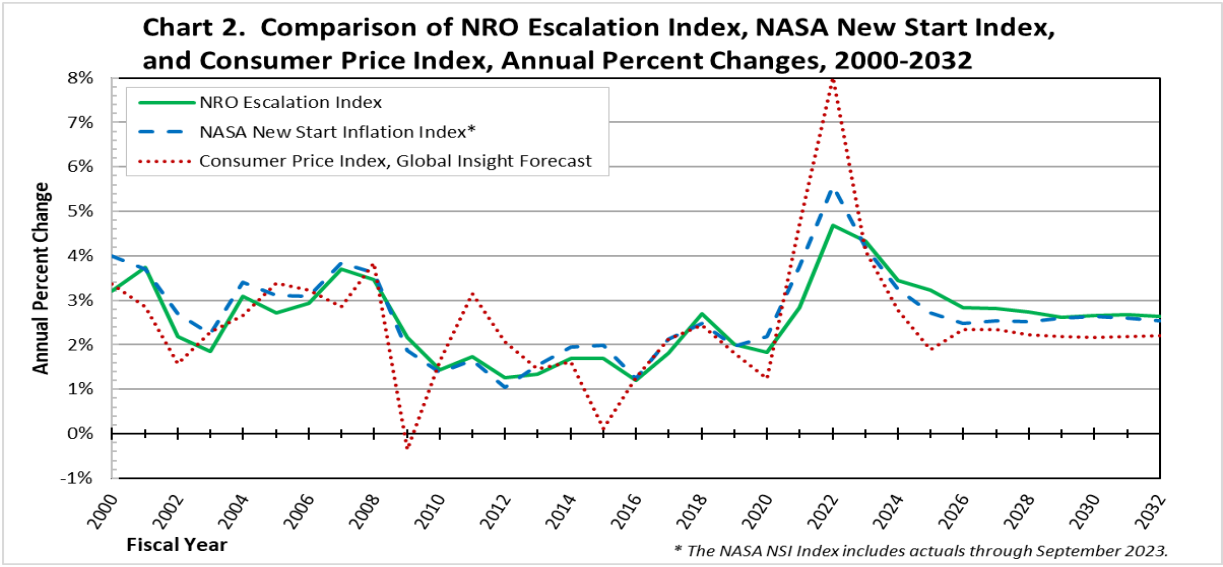
Component	Basis	Comments
Space/Ground Weighting	FY 2022 study weights	Captures enterprise costs as well as traditional space and ground acquisition costs.
Element of Cost Weighting	FY 2022 study weights	Includes Space and Ground data.
Outlay Rates	Prior to 1998: 1998 Pres Budget rates 1999 - 2009: Corresponding year PB rates 2010 - 2023: Annual NRO Budget rates 2024 - : Average of 2022-23 NRO Budget rates	Transitioned to NRO outlays applying for 2010+. Averaged outlay rates of last two years for 2024 and beyond
Escalation Index	1960 - 2021: Published NRO changes 2022 - 2034: S&P Global data/forecasts 2035 - : Geometric mean of 1996-2023 change	Minor S&P Global revisions possible for past couple of years with future years subject to change with subsequent S&P Global releases

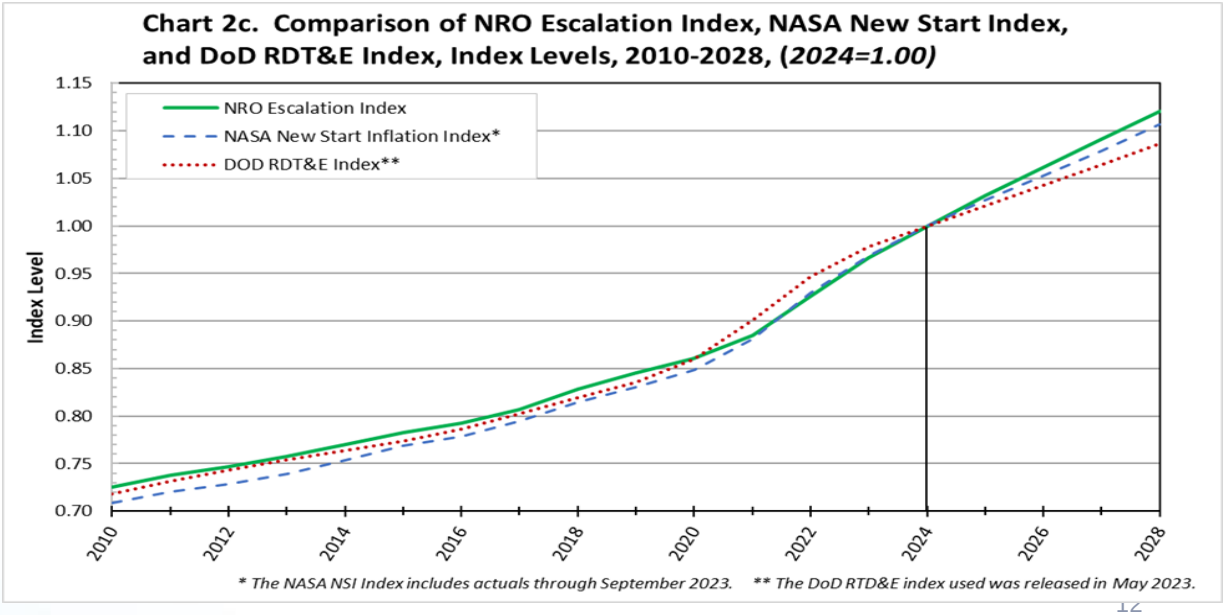
- Labor and Material costs each rose 4.4% in FY 2023 while ODCs rose 3.2%
- Materials and ODCs have been more volatile the last few years
- Labor represents over 81% of the NRO Escalation Index
- Labor costs are forecast to rise more than Materials or ODCs going forward



Comparison with Other Indexes

- The NRO Escalation Index (+4.3%) rose at a rate very close to the NASA New Start Index (+4.2%) and the Consumer Price Index (+4.1%) in 2023
- The NRO Index is forecast to increase slightly more than the other two indexes from 2024 – 2028
- The NRO Escalation Index rose only slightly less than the NASA New Start Index and the DOD RDT&E Index from 2018 to 2024, but is forecast to rise more through 2028





NRO's Realistic Cost Estimates

RCE

The Problem

- Government contracts have a tendency to grow in value
  - Scope growth
  - Cost growth because initial award is too low
- Difficult to evaluate cost realism in BOE source selections
  - Source Selection team adjust hours up or down based on experience
  - Historically adjustments to reach a Probable Cost (PC) have been small
- Contracts that experience significant growth drive execution challenges and diminish the health of the larger portfolio

The Solution… Establish a data-driven process!

- NRO's Realistic Cost Estimates (RCEs)
  - Focus proposal cost evaluations on cost realism, not proposed cost
  - Leverage wealth of NRO historical program cost databases and methods
  - Emphasize historical performance as basis for cost proposals

- A new concentration, not a radical change
  - Enables Government to substantiate estimate of costs at the unit level
  - Leverages technical team evaluation of technical parameters

- Designed to mitigate Offeror "buying in" to the contract
  - Decreases cost risk
  - More realistic proposals that are executable within budget

Improves NRO's understanding of true acquisition cost
Minimizes unanticipated cost growth

RCE Process

1. Request similar vendor information as required for independent estimates: ***Section L***
2. Encourage offerors to bid commensurate with their historical performance: ***Section M***
3. Evaluate proposal at comparable levels to CAAG cost estimates
4. Accept proposed costs for each element when well substantiated
5. Correct or replace elements not substantiated
6. Award contracts with better defined risks at a realistic contract value with lower expected growth

Results

- RCE method has been used with competitive and sole-source awards
  - Contracts awarded on or ahead of schedule, without protest
  - Cost evaluations were more rapid than BOE approach
  - Reduced quantity of RCEs (100+) compared to BOEs (1000+)

- RCEs are built on a foundation that prioritizes the use of historical data and applies standard cost estimating methods

- Recent RCEs have been positive, NRO will continue to track final program outcomes and monitor overall portfolio health

CER DEVELOPMENT TOOLS

Our Foundation – Data
The NRO CAAG Cost CDRL

- Cost CDRL is the “life blood” of the NRO CAAG
  - Cost CDRL established in late 1990’s by direction of DD/NRO

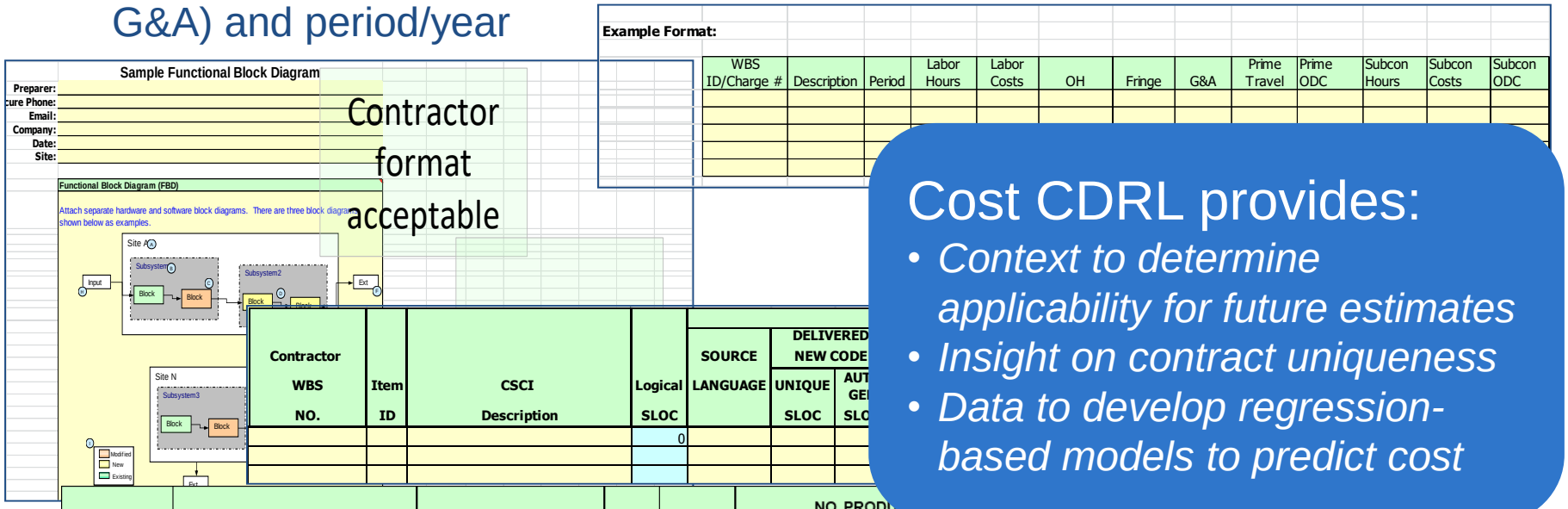
- Main components of Cost CDRL
  - Mapping contractor cost accounts to Standard WBS “End-Items”
  - CAAG Data sheets – technical data linked with cost data
  - Mission and system overviews
  - Contract programmatic information – schedules, contract history, etc

- Deliverables – PDR, CDR, IOC/FOC and includes provision for additional deliveries if warranted

Quality of CAAG CERs and Estimates is directly related to the quality of our Cost, Programmatic and Technical data

Information on CAAG's Cost CDRL

- Contract history, period of performance, schedule milestones, etc.
- System information, including functional block diagram
- Technical Characteristics such as mass, quantities, and *UCC-G Code Counts*
- Acquisition/Development process information
- Accounting Data by element of cost (e.g., labor, material, fee, labor overhead, G&A) and period/year



Example Format:

WBS ID/Charge #	Description	Period	Labor Hours	Labor Costs	OH	Fringe	G&A	Prime Travel	Prime ODC	Subcon Hours	Subcon Costs	Subcon ODC

Sample Functional Block Diagram

Preparer:
Phone:
Email:
Company:
Date:
Site:

Functional Block Diagram (FBD)

Attach separate hardware and software block diagrams. There are three block diagrams shown below as examples.

Contractor format acceptable

Contractor WBS NO.	Item ID	CSCI Description	Logical SLOC	SOURCE LANGUAGE	DELIVERED NEW CODE UNIQUE SLOC	AUT GE SLC
			0			

WBS NO.	UNIT DESCRIPTION	UNIT WEIGHT (LBS.) BASIC	% MGA	PRED	NO. PER SYS	WT PER SYS	NO. PRODU FLIGHT-UNIT EQUIVALENTS DEV (NR) E	TQ	PROD (R) PQ	F	S	R	% UNIQUE DESIGN	% NEW DESIGN	1ST TIER	2ND TIER	($M) NR	REC	TOTAL	T1
01	Electronic Box Example	12.0	30	15.6	2	31.2	0.8		1	3			66	33						

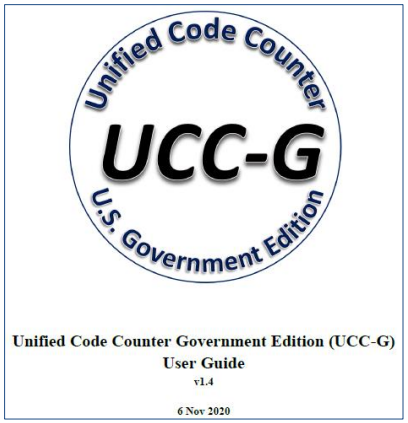
Cost CDRL provides:

- *Context to determine applicability for future estimates*
- *Insight on contract uniqueness*
- *Data to develop regression-based models to predict cost*

Unified Code Counter – Government (UCC-G) Edition

DESCRIPTION

- UCC-G was developed in 2016 as the standard software metrics counting tool across IC and DoD major Acquisition programs
  - NRO Cost and Technical Data Report (CTDR) Cost and Technical Data Requirements List (CDRL)
  - DoD Software Resources Data Reporting: Development, Maintenance and Enterprise Resource Planning Development Reports, and Data Dictionary
- The software is loaded and run at the contractor site to count source code and can be used on both classified and unclassified systems
- An end user of the UCC-G will use the tool to
  - Count source lines of code (LOC) to collect metrics or
  - Difference two software baselines and generate a differential report
- Code counts are the basis of the CAAG's software size and cost estimation



TOOLS

Last Updated: 2020

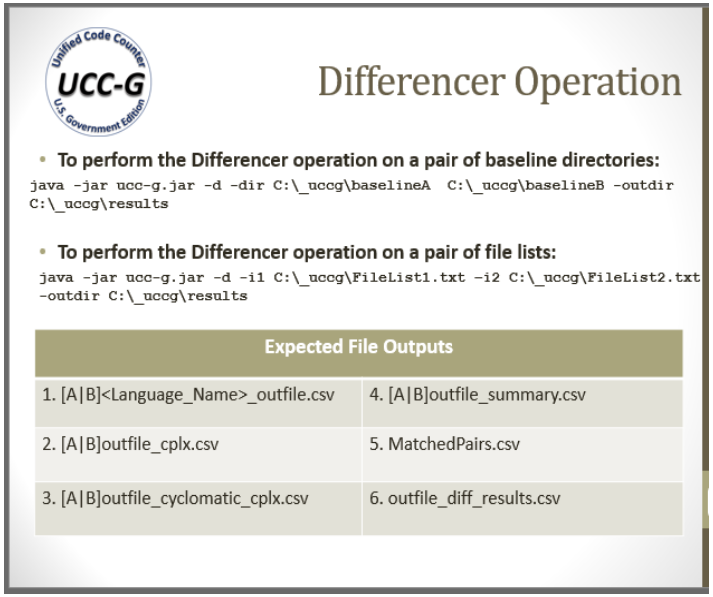
Released to Gov't & Industry

Developed by CAAG
SME: Data Team

Requirements:
1. UCC-G User Guide
2. Executable JAR file

SCOPE

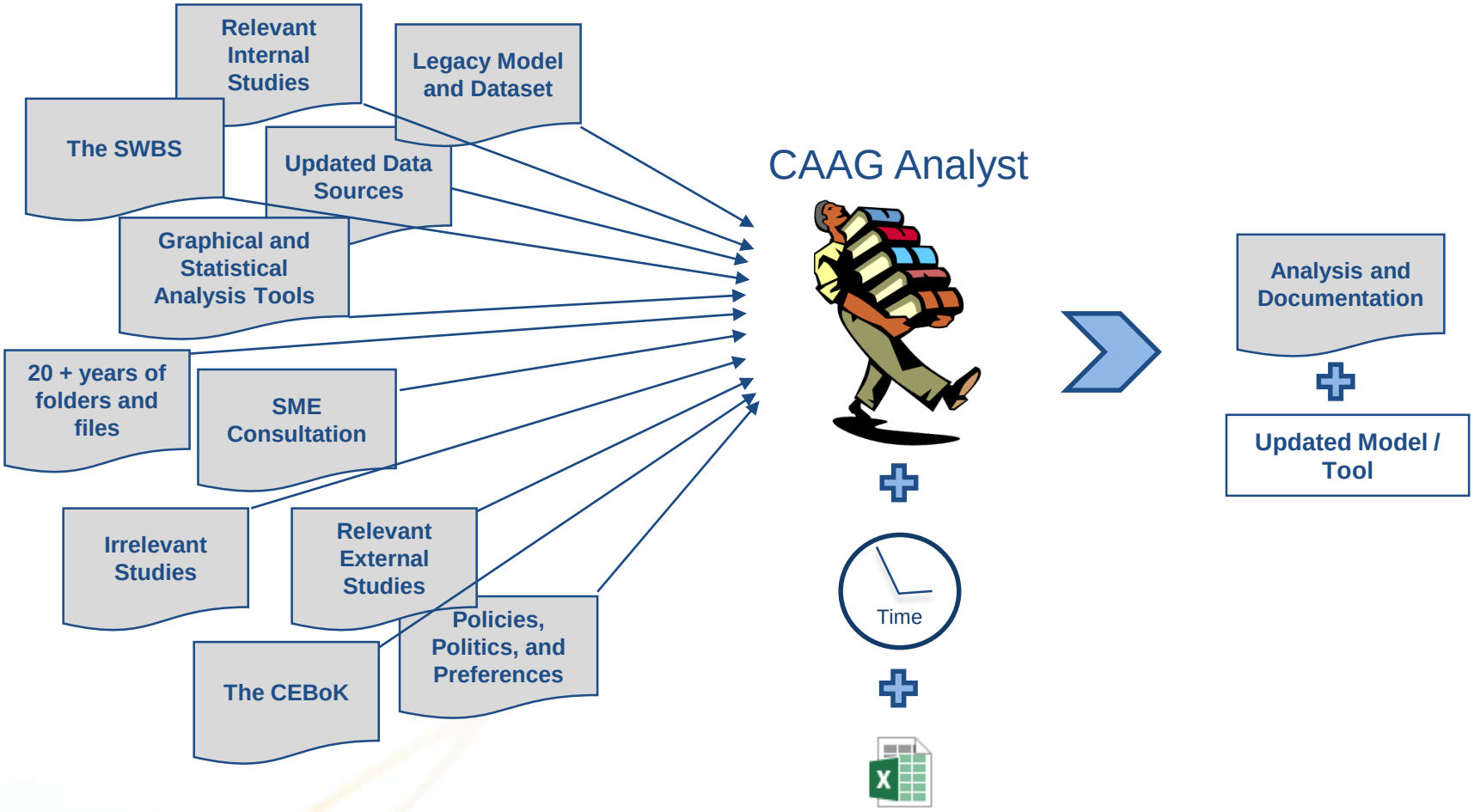
- UCC-G output metrics include Physical and Logical LOC, blank lines, comments, compiler directives, executable instructions, keywords, differencing, duplicates, and cyclomatic complexity
- Collects software metrics consistently for over 30 programming languages and languages not yet identified (e.g. custom/proprietary languages or standard languages not yet integrated into UCC-G)



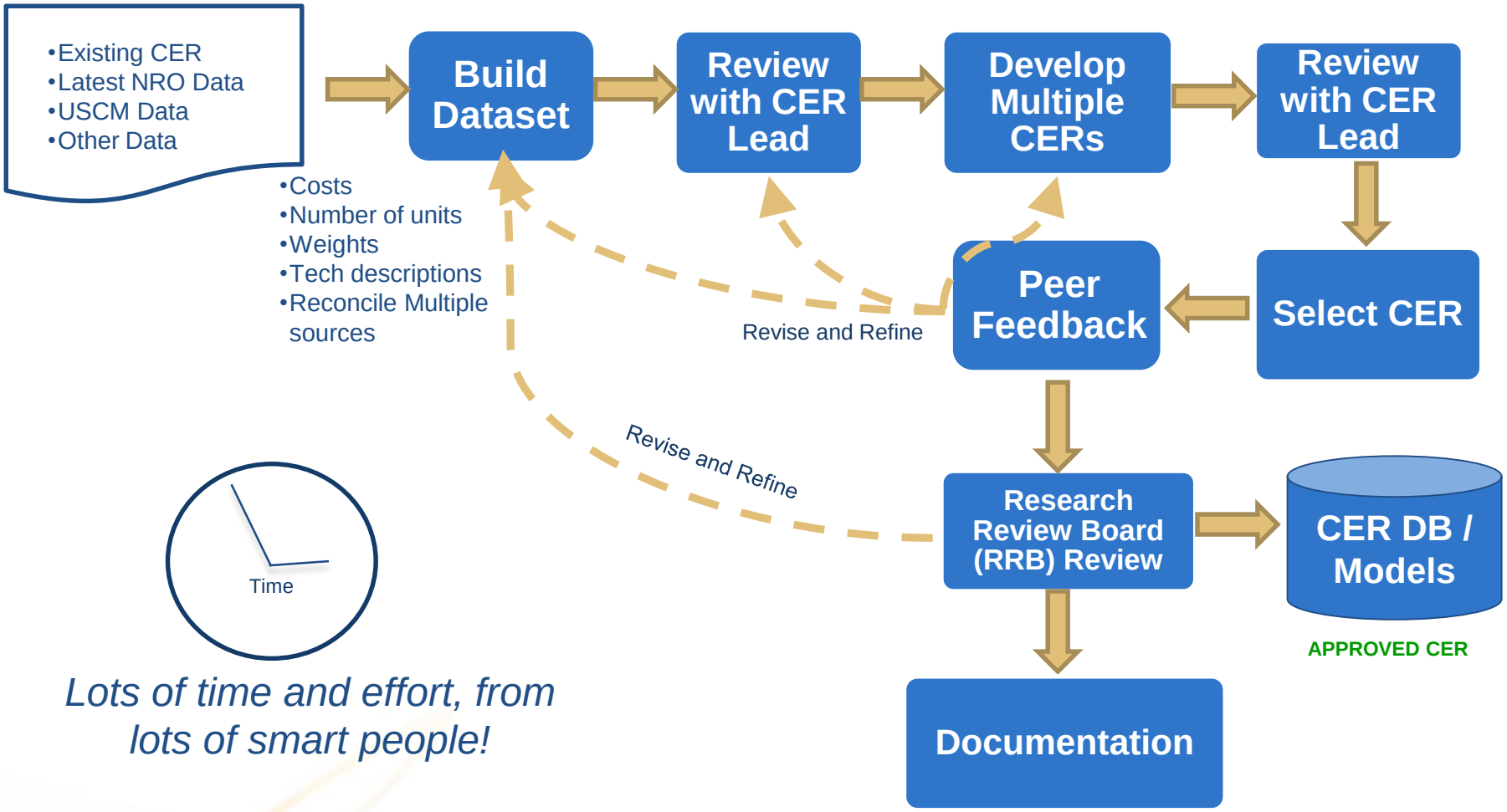
THINGS TO CONSIDER

- The UCC-G application is distributed as an executable Java Archive file
- Check for the most recent software release - Currently v1.4.4
- **New Release anticipated in May 2024 – v 1.5**

Cost Analysis is Hard



NRO CAAG CER Management Process



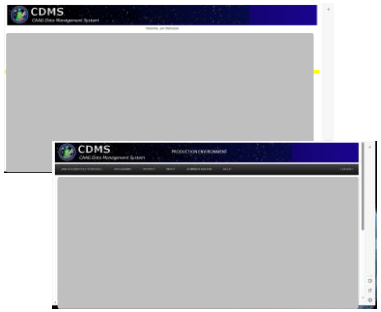
Lots of time and effort, from lots of smart people!

Standardized tools can help this process take less time

CAAG CER Development Tools

CAAG Data Management System (CDMS)

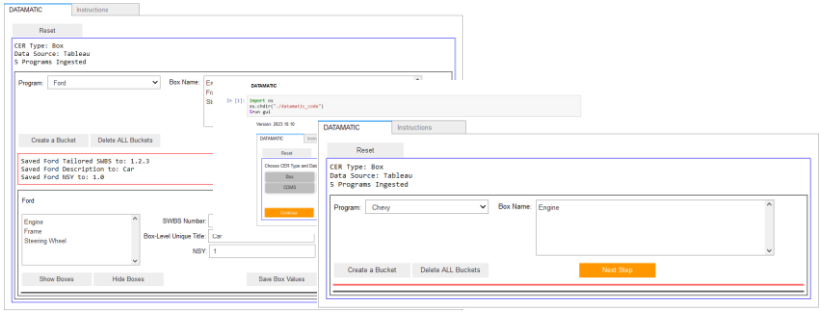
- MS SQL database of Space program cost and technical data "profiles" accessible via:
  - Web-enabled user interface
  - SQL queries
  - Tableau and other software



- Data validation during ingest helps to ensure consistency
- Structure and tags allow access to and discovery of NRO CAAG's summarized SWBS-aligned data in a central, shared, location

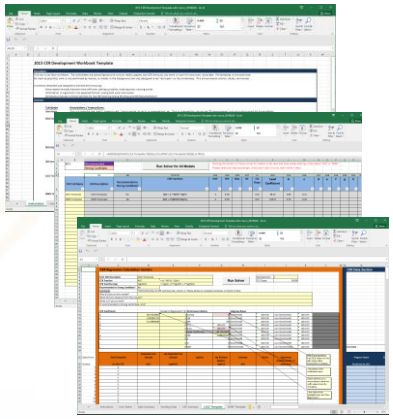
DATAMATIC

- Python based tool, automates typical data conditioning steps for CAAG hardware CERs
- Enables alignment of CAAG data and CAAG methods, without forcing changes to CDMS



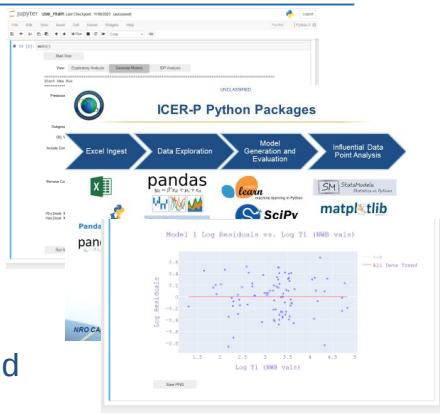
CER Development Template

- Excel-based template for regression analysis
- Spreadsheet form leaves operations open for review
- Template provides structure, but also allows flexibility and traceability of a spreadsheet
- Created in 2015, but still great for teaching and learning, and for documentation of results



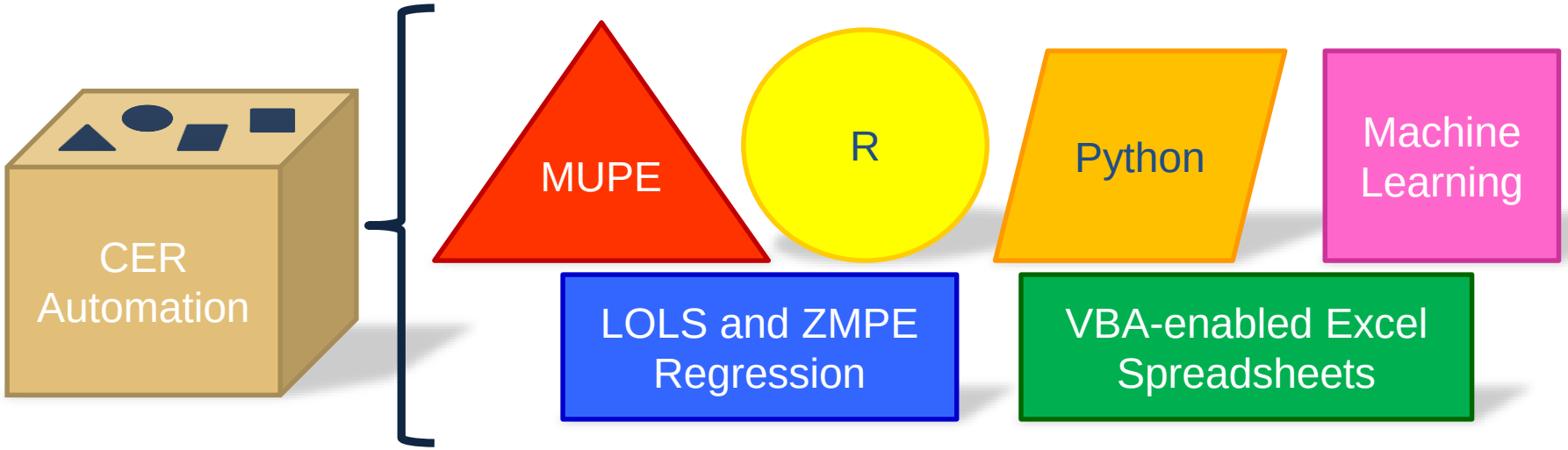
ICER-P

- Python based tool for regression analysis, with an interactive user interface
- Automatically generates functional forms for all combinations of predictors
- Enhanced visualizations for both exploratory analysis and plotting of model's results



- Current version is not comprehensive, but is a great basis for a configurable CER tool with automated features

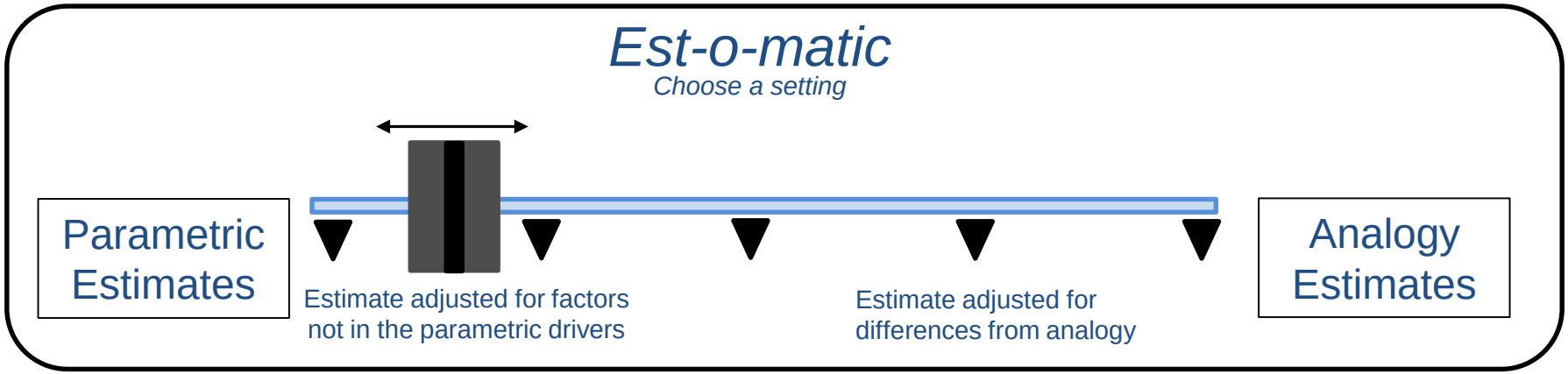
Improving CER Development



The CAAG is figuring out where some newer blocks fit into a more automated CER development process

Digressing from Regression

- CAAG estimators often make analogy-based adjustments to parametric estimate results
  - Calibration to like program data in the CER data set
  - Adjustment for factors that are not among the drivers



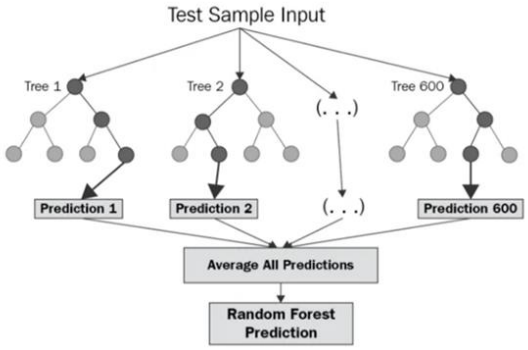
- Many machine learning techniques would result in the selection of a subset of “like” programs based on a collection of parameters
  - Aren’t these more like analogy estimates then?

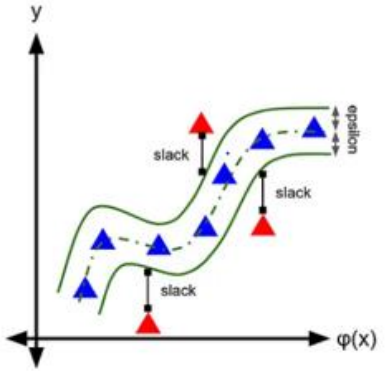
Does the CAAG have to choose?

Machine Learning Techniques

- Imputation and scaling
- Clustering Techniques
  - K-Means
  - Principal Components Analysis(PCA)
  - Variable Eigenvectors
  - Dissimilarity Scores
  - Agglomerative Features
- Linear Regression Variants
  - LOLS, MUPE, ZMPE
  - Lasso, Ridge (Regularization)
- Decision Trees
  - Random Forest
  - Gradient-Boosted Machines
- Nearest Neighbor (KNN)
- Support Vector Machines
- Neural Nets

"Machine Learning for Cost Analysis"





We see potential for the application of a variety of Machine Learning techniques in our models

THE MAAC MODEL

Estimating Non-traditional Acquisitions

2008 → Different models for different acquisition strategies

- Traditional military/civil
- Commercial-like
- Demonstrations

2009 → NRO Director: "*focus on the cost of varying levels of mission assurance*"

2013 → Initial suite of models that quantify cost of standards*:

- Parts, materials, and processes (PMP)
- Environmental testing

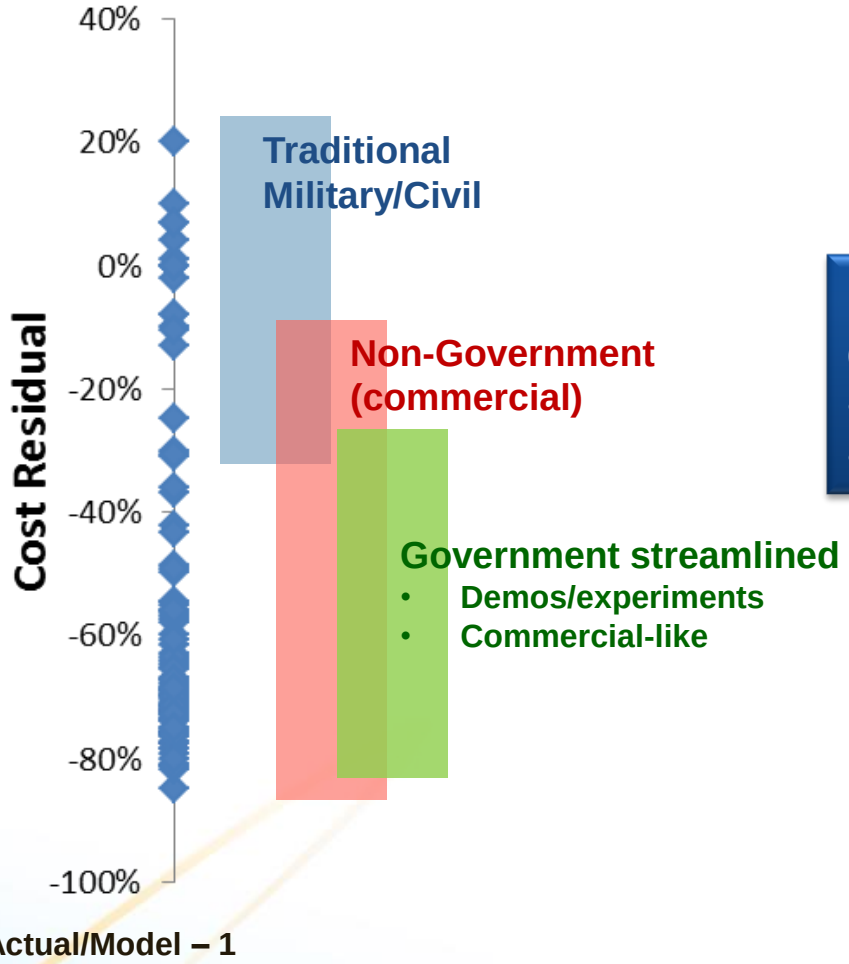
2016 → Unified model: Mission Assurance and Acquisition Complexity (MAAC)

- Mission assurance / oversight / contracting / industrial base
- Based 93 commercial and Government systems (2 NASA)
- Used in almost every estimate
- Continuously updated

* Burgess et al., *Cost of Mission Assurance for Space Programs*, 2013 ICEAA Professional Development and Training Workshop, New Orleans, LA, June 2013.

A Cost Continuum

Our traditional satellite cost model vs.
93 completed programs:



Demos and commercial acquisitions can cost a lot less
- Not a fixed decrement
- Details matter

MAAC Formulation

MAAC Incorporates Results from Separate Studies into Single Dataset.

- Adds other programmatic drivers hypothesized to drive cost.
- Model weighting factors by regression of all data.

$$\text{MAAC Score} = \left[\text{CAPS}^{*}\text{Score}\right]\cdot\alpha + \left[\text{Parts score}\right]\cdot\beta + \left[\text{Test score}\right]\cdot\chi + \left[\text{contract type: FFP, FPI, CP}\right]\cdot\delta + \sum\left[\text{other programmatics}\right]\cdot\omega_i$$

*CAPS Score (Commercial Acquisition Program Study) includes contracting and oversight details.

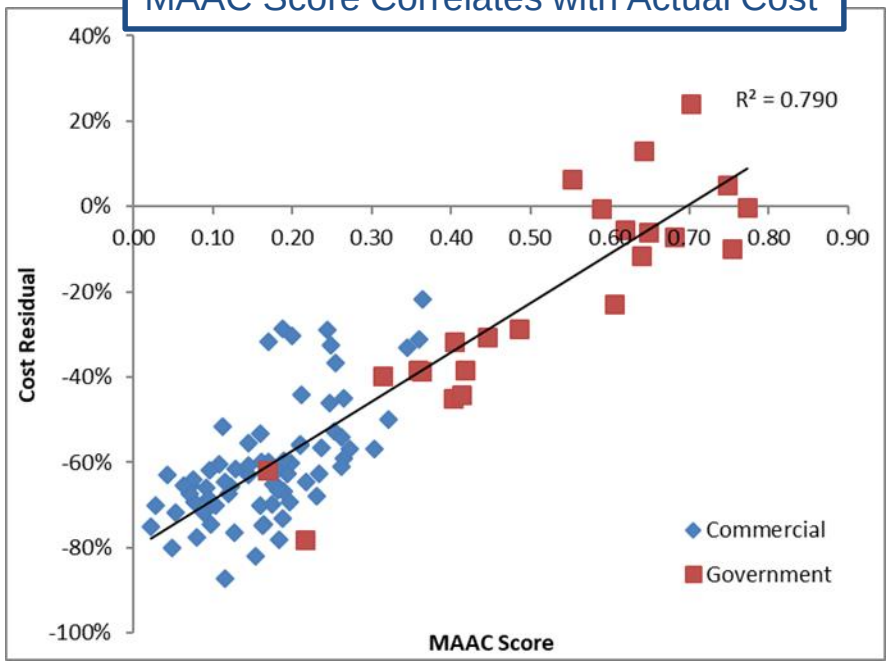
Alvarado, Wilmer, D. Barkmeyer and E. Burgess. Commercial-Like Acquisitions: Practices and Costs. *Journal of Cost Analysis and Parametrics,* Volume 3, Winter/Spring 2010.

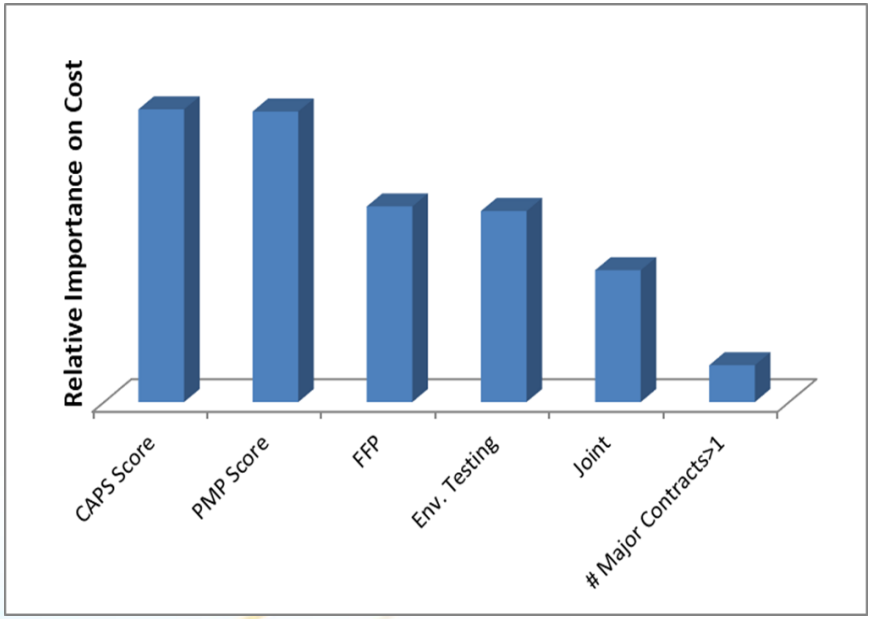
MAAC: Executive Overview

Scores the mission assurance and acquisition complexity of any satellite acquisition

Predicts adjustment to traditional cost-model result

MAAC Score Correlates with Actual Cost





Influenced by:

- Mission Assurance practices
- Oversight & contracting details

Collaboration with NASA

LAUNCH INTEGRATION COST MODEL

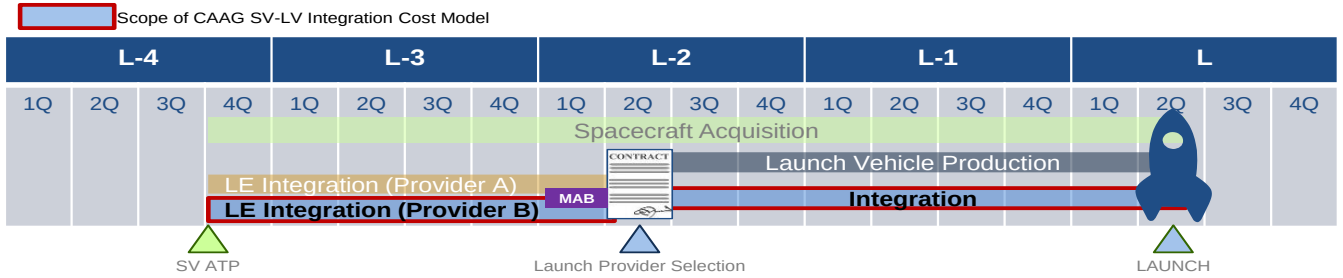
Launch Service Cost Modeling

- The NRO CAAG develops Launch Service Cost Models
  - NRO has been independently estimating costs associated with launch service for the last 14 years
  - Models used to support:
    - Negotiations on EELV and successor NSSL contracts
    - NRO-internal launch service contract cost estimating
    - NRO budget planning
    - NRO AoA studies
- NRO CAAG supports continuing engagement with launch service providers through Launch Cost Summit, modeled after CIPT
- NASA/LSP shared cost data with NRO CAAG data on recent launch procurements
  - Enabled case study demonstrating applicability of NRO CAAG cost models to NASA launch service procurement

Success in a recent collaborative cost analysis study with NASA

Scope of SV-LV Integration Effort

"Integration": Multi-year engineering effort performed by a launch service provider ensuring compatibility between spacecraft and launch vehicle & facilities, enabling mission success



Mission Design & Analysis

Manage/Validate Launch Base Interfaces & Infrastructure Requirements

Manage/Validate SV-LV Interface Requirements

Mission-Unique HW Design

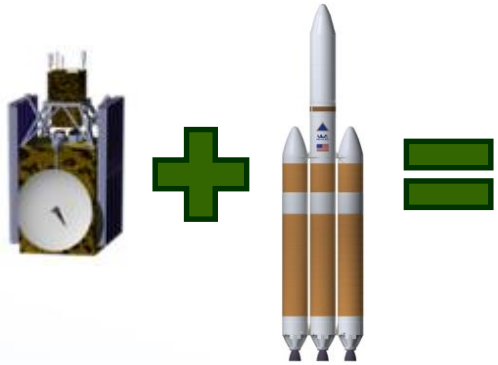
Coupled Loads Analysis

Launch Rehearsals

Trailblazers

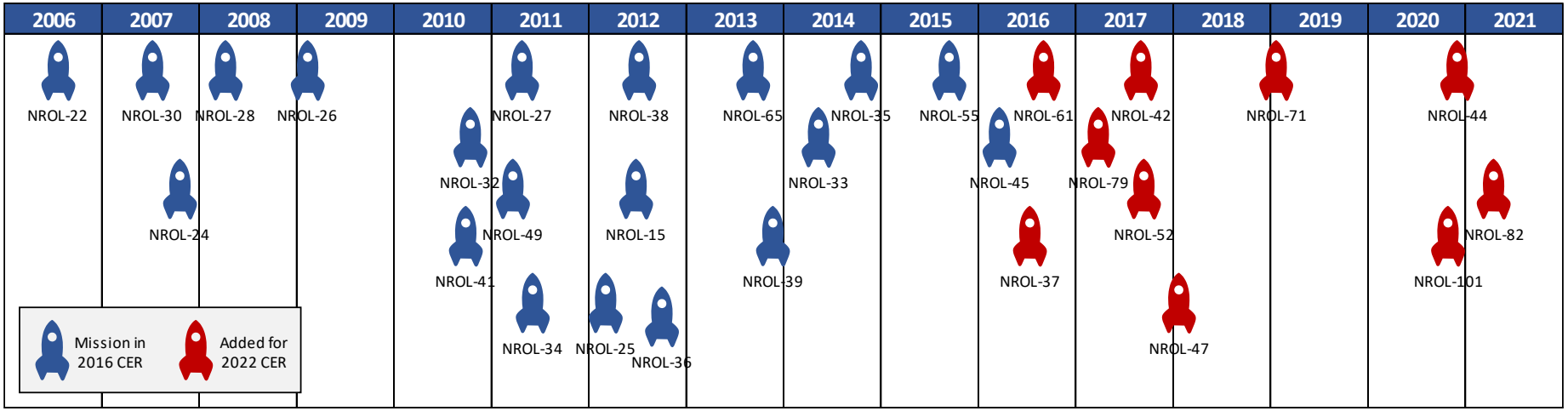
Trajectory Planning

Aerophysics, Thermal, Contamination



NRO / BPO / CAAG

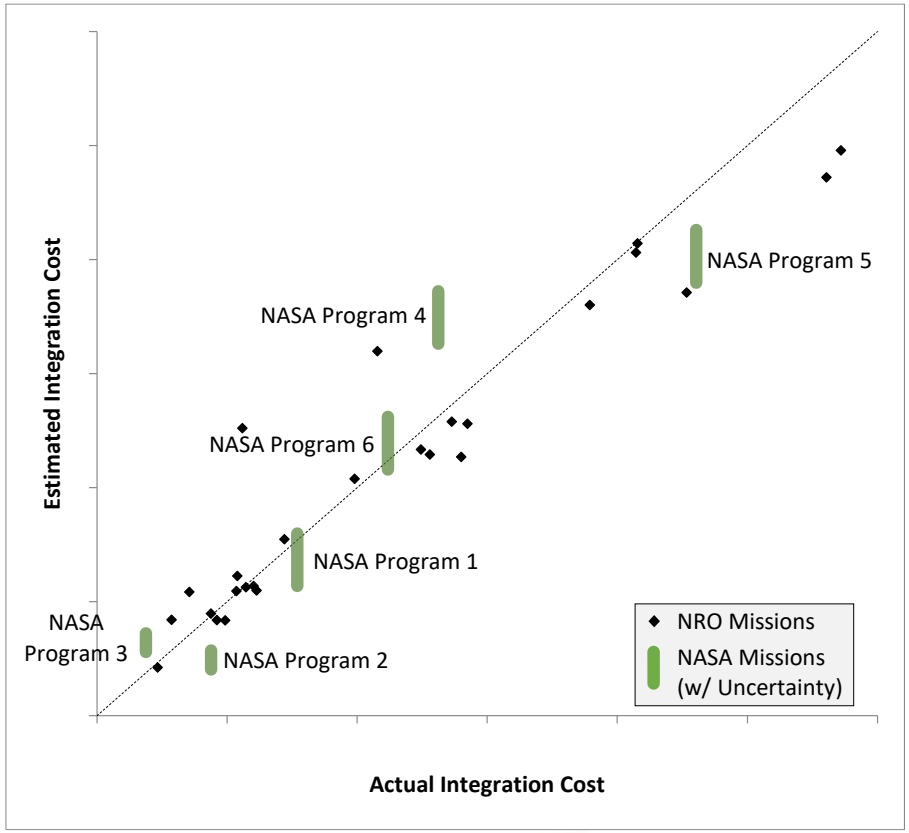
CAAG SV-LV Integration Cost Model Dataset



- Previous update to CAAG Integration CER – 2016
  - Briefed at NRO/Air Force Launch Cost Summit, 2018

- 2022 dataset expanded to include total of 30 missions
  - Mix of Heavy & Medium/Intermediate, Eastern & Western ranges, First-time & recurring
  - Broad ranges represented in integration cost, ICD requirements count, number of WDRs performed, trailblazer activities required

NASA Data in NRO CAAG Integration CER



	Points	SPE	Bias
NRO Data	30	22.5%	0%
NASA Data	6	43.8%	7.5%

- Missing data results in some uncertainty around Integration Complexity scoring for NASA missions
- NASA integration costs appear to be in-family with NRO costs
- NASA integration costs appear to be driven by the same parameters that drive NRO costs

CER appears to be a good predictor of SV-LV integration costs independent of customer

Summary

- Launch cost is an increasingly variable part of enterprise-level trades for US government satellite constellation architectures
- NRO CAAG has developed a parametric cost model for the highest-variability portion of launch cost, SV-to-LV Integration Engineering
- Integration cost is predicted well by two categories of cost drivers:
  - **Mission assurance** drivers related to familiarity and LV provider proven capability with the specific requirements of the mission – First-time SV-LV design pairing, First-time customer use of LV, Heavy-lift LV
  - **Integration complexity** drivers related to the scope of the mission-specific tasks to be performed – ICD requirements, customer-directed studies, mission-unique environmental control equipment, use of western range
- NRO CAAG cost model shows good agreement with NRO and NASA historical data

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