ASCoT : *The Official Release*

A Web-Based Flight Software Estimation Tool

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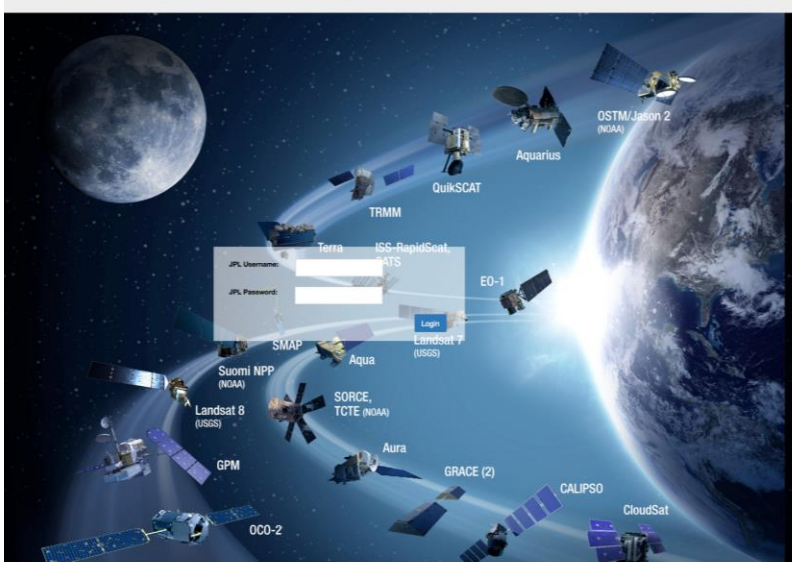

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Introduction & Background

- ASCoT is the NASA Analogy Software Cost Tool
  - ASCoT has been under development for 3 years based on 10 years of research
  - The purpose of ASCoT is to
    - Supplement current estimation capabilities
    - Be effective in the very early lifecycle when our knowledge is fuzzy
      - uses high level systems information (Symbolic Data)
    - Be usable by Cost Estimators, Software Engineers and Systems Engineers
  - Methodology handles
    - small sample sizes and noisy data
  - Previous talks and papers described the research approach and activities
    - ICEAA 2014, 2015
    - NASA Cost Symposium 2014, 2015, 2016
    - IEEE Aerospace 2016, 2017, 2018 (forthcoming)
    - Numerous research publications in IEEE Software, lead by Dr. Tim Menzies et.al.

Reminder: What We Learned So Far

- There are a variety of models whose performance are hard to distinguish (given currently available data) but some models are better than others
- If one has sufficient data to run COCOMO or a comparable parametric model then the best model is the parametric model
- When insufficient information exists then a model using only system parameters can be used to estimate software costs with 'acceptable' reduction in accuracy. The main weakness is the possibility of occasional very large estimation errors which the parametric model does not exhibit.
- Use MRE to supplement standard statistical evaluation metrics
- Use median over average when possible
- While a nearest neighbor method performs as well as clustering models based on MMRE, clustering handles outliers better and provides a structured model that supports cost analysis and not just prediction

Major Changes to ASCoT

- Added Nearest Neighbor (KNN) and COCOMO II
- More and Improved Mission Data
- Improved Input Parameters
  - Redefined mission type into two parameters destination and a new mission type parameter to improve specificity
  - Removed lines of code
    - even as a categorical parameter it can be difficult for people to assess, especially those with limited software experience
  - Removed Secondary Element
- Changed Clustering algorithm
  - Based on extensive analysis of four different clustering methods
- More extensive evaluation criteria
  - MRE, cluster stability, effort variation
- ASCoT almost runs on ONCE as a web-based tool !!
  - 1 last problem

"ASCoT" Key Estimation/Analysis Components

Analogy

Cluster Analysis
- Clustering
- Development Effort Estimate

Major Update

Knn Analysis
- Nearest Neighbor
- Development Effort and SLOC Estimate

New

Regression Analysis
- Linear Regression
- Development Cost Estimate

Updated

COCOMO II
- Verified Reproduction
- Cost/Effort

New

- Cluster & Regression Analysis components listed rely on high level Mission Descriptors such as # of Instruments and Mission Type
- COCOMO II is a reproduction and uses traditional inputs
  - Will be linked to Analogy Cluster Model in future release

Data Sources

- Where the data came from
  - CADRe
  - NASA 93 – Historical NASA data originally collected for ISS (1985-1990) and extended for NASA IV&V (2004-2007)
  - Contributed Center level data
  - NASA Software Inventory
  - Project websites and other sources for system level information if not available in CADRe

Missions by Destination

Total of 51 missions with data

- 47 can be used in at least 1 of the estimation models

Missions by Destination

- Earth – 23
- Asteroids/Comets – 7
- Inner Planets– 17
- Outer Planets - 4

New Missions Added:

- LADEE
- MMS
- Solar Probe Plus

Earth	Asteroids/Com	Inner	Outer
Van Allen Probe	DS1	Mars Odyssey	GLL
OCO	Stardust	Genesis	JUNO
SDO	Deep Impact	MRO	New Horizons
SMAP	OSIRIS REX	Maven	Cassini
GPM Core	Dawn	Messenger	
NuStar	NEAR	Solar Probe Plus	
GEMS	Contour	LRO	
GLORY		Grail	
GOES-R		LCROSS	
GEOTAIL		LADEE	
EO1		Kepler	
Aqua		Stereo	
GLAST		MPF	
NOAA-N-Prime		MER	
NPP		MSL	
LDCM		Phoenix	
RHESSI		Insight	
TIMED			
IRIS			
MMS			
HST			
GRO			
WISE			

Data Summary – Key Metrics

- Effort, Lines of Code and Productivity by Destination

Destination	# of Records	Effort (Months)		Logical Delievered LOC	
		Median	S.D.	Median	S.D.
Astreroids/Comet	7	546	373	143,000	35,189
Earth	23	499	466	62,000	39,986
Inner	17	664	435	122,000	133,765
Outer	4	620	411	54,000	21,633

- Number of Deployable and Instruments by Destination

Destination	Instrument		Deployable	
	Median	Range	Median	Range
Astreroids/Comet	3	2-5	1	0-3
Earth	3	1-10	2	0-8
Inner	4	3-10	2	0-10
Outer	10	7-12	3	0-8

Improved Input Parameters

- Original Mission-Type parameter combined type of Mission Type with Destination

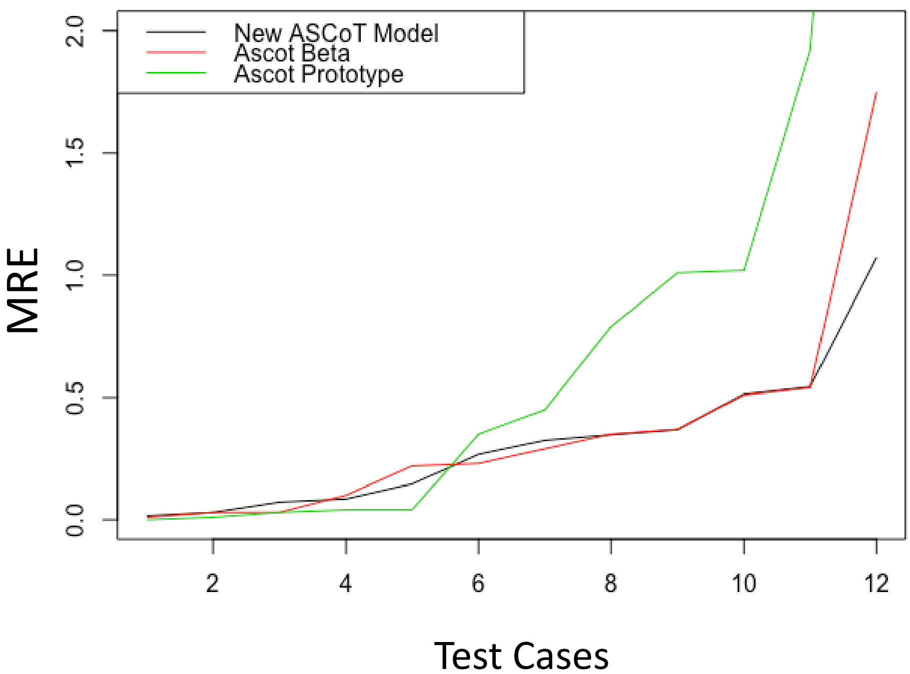
Mission Type	**Values**	**Description**	**Example**
	Orbiter	A Robotic spacecraft that orbits or it's target body. Also includes flyby spacecraft.	Aqua, New Horizons
	Observatory	Observatories are space based telescopes that support space based astronomy across a wide set of frequencies. They can be earth trailing or at the various LaGrange points created by the gravity fields of the eartb, sun and moon.	Kepler
	Lander	A robotic spacecraft that does its science in-situ or from the surface of a solar system body. It does not move from its original location.	Phoenix
	Rover	A robotic spacecraft that does its science in-situ or from the surface of a solar system body and has the ability to move on the surface. To date all rovers have wheels but in the future they may crawl, walk or hop.	MSL
Destination	**Values**	**Description**	**Example**
	Earth	Missions that are in an Earth orbit.	OCO
	Inner Planetary	Missions that target planets within the asteroid belt. Also includes missions that are Heliocentric, Earth leading or trailing, at the Earth-Sun-Moon LaGrange points, and lunar mission.	Maven
	Asteroid/Comet	Missions that target asteroids or comets. As these may typically require more complex, or different, trajectories than inner planetary missions.	Dawn
	Outer Planetary	Outer Planetary missions are missions that travel beyond the asteroid belt.	JUNO

Changed Clustering Algorithm

- ASCoT Beta used spectral clustering to derive the clusters
- Conducted extensive analysis to verify this was indeed the best method
  - Spectral Clustering
  - K-Means
  - Hierarchical Clustering
  - PCA- Principle Components
- The methods were examined for
  - cluster membership stability
  - minimum within-cluster range
  - Effort estimation error based on leave-one-out MRE

Model MRE Performance

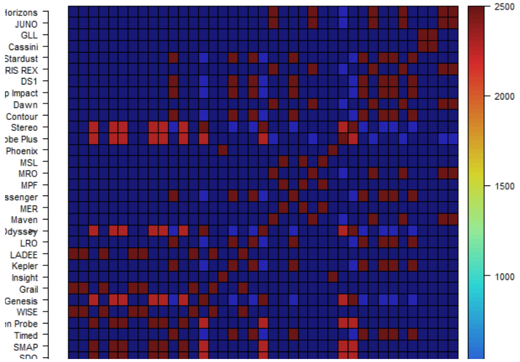
Model Estimation Error, based on MRE, shows dropping SLOC as an input did not reduce estimation accuracy

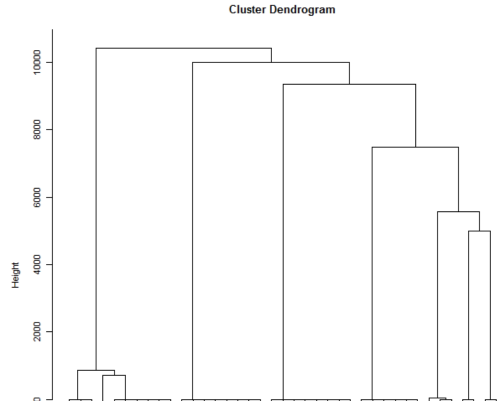


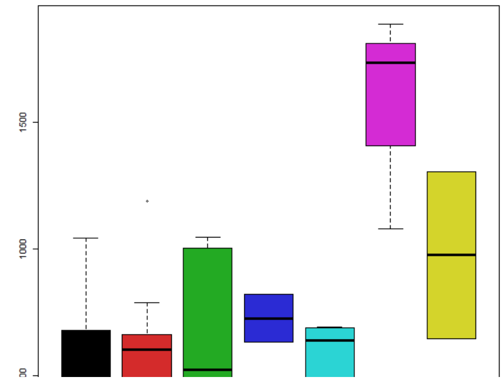
MRE Comparison Based on Test Cases

		ASCoT Prototype	ASCoT Beta	ASCoT
	1	0%	1%	2%
	2	1%	3%	3%
	3	3%	3%	7%
Inner Quartile	4	4%	10%	8%
Inner Quartile	5	4%	22%	15%
Inner Quartile	6	35%	23%	27%
Inner Quartile	7	45%	29%	32%
Inner Quartile	8	79%	35%	35%
Inner Quartile	9	101%	37%	37%
	10	102%	51%	51%
	11	192%	54%	54%
	12	506%	175%	107%
Median MRE		40%	26%	30%
Average MRE		89%	37%	32%

Expanded Model Evaluation Criteria



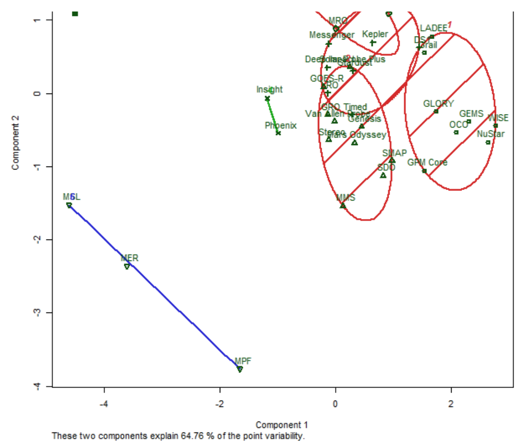


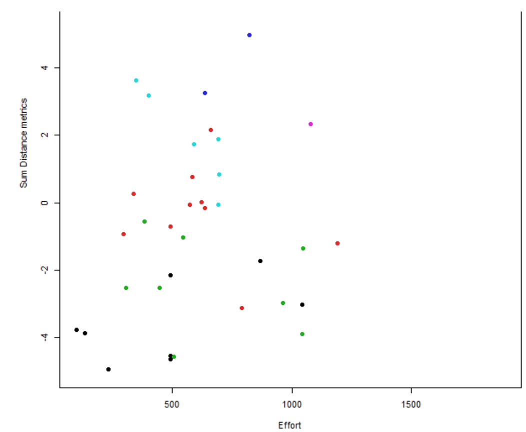


For detailed discussion come to the breakout session!

Mission	Effort	Dest	Type	Grp
GEMS	100	Earth	Orbiter	1
GLORY	133	Earth	Orbiter	1
GPM Core	1043	Earth	Orbiter	1
NuStar	493	Earth	Orbiter	1
OCO	492	Earth	Orbiter	1
WISE	233	Earth	Orbiter	1
Grail	868	Inner	Orbiter	1
LADEE	492	Inner	Orbiter	1
GOES-R	584	Earth	Orbiter	2
GRO	492	Earth	Orbiter	2
MMS	662	Earth	Orbiter	2
SDO	1190	Earth	Orbiter	2
SMAP	789	Earth	Orbiter	2
Van Allen Probe	295.6	Earth	Orbiter	2
Genesis	637	Inner	Orbiter	2
Mars Odyssey	336	Inner	Orbiter	2
Solar Probe Plus	621	Inner	Orbiter	2
Stereo	571.6	Inner	Orbiter	2
Timed	504	Earth	Orbiter	3
Kepler	446	Inner	Orbiter	3

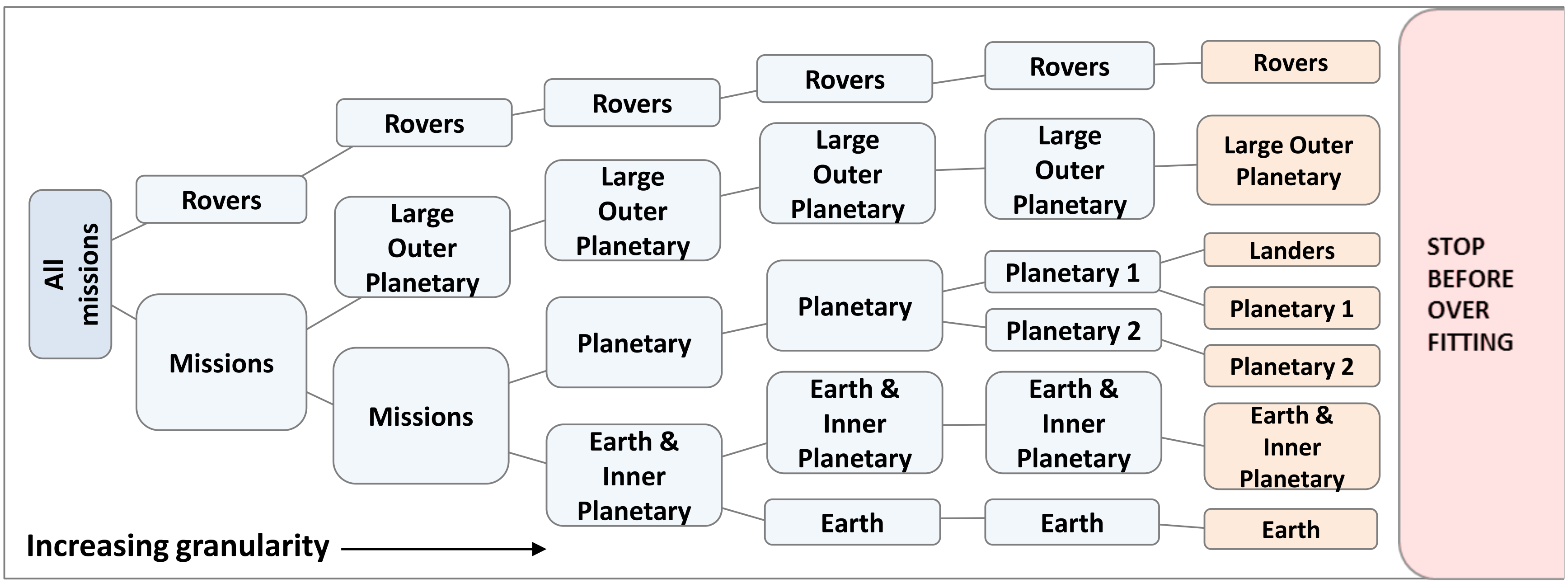
Mission	Effort	Dest	Type	Grp
LRO	964	Inner	Orbiter	3
Messenger	384.4	Inner	Orbiter	3
Contour	307	Ast/Com	Orbiter	3
Deep Impact	1047.9	Ast/Com	Orbiter	3
DS1	1042.8	Ast/Com	Orbiter	3
Stardust	546	Ast/Com	Orbiter	3
Insight	822	Inner	Lander	4
Phoenix	634	Inner	Lander	4
Maven	694	Inner	Orbiter	5
MRO	691	Inner	Orbiter	5
Dawn	691.43	Ast/Com	Orbiter	5
OSIRIS REX	401.01	Ast/Com	Orbiter	5
JUNO	346	Outer	Orbiter	5
New Horizons	591.1	Outer	Orbiter	5
MER	1735.4	Inner	Rover	6
MPF	1080	Inner	Rover	6
MSL	1888	Inner	Rover	6
Cassini	1307	Outer	Orbiter	7
GLL	648	Outer	Orbiter	7





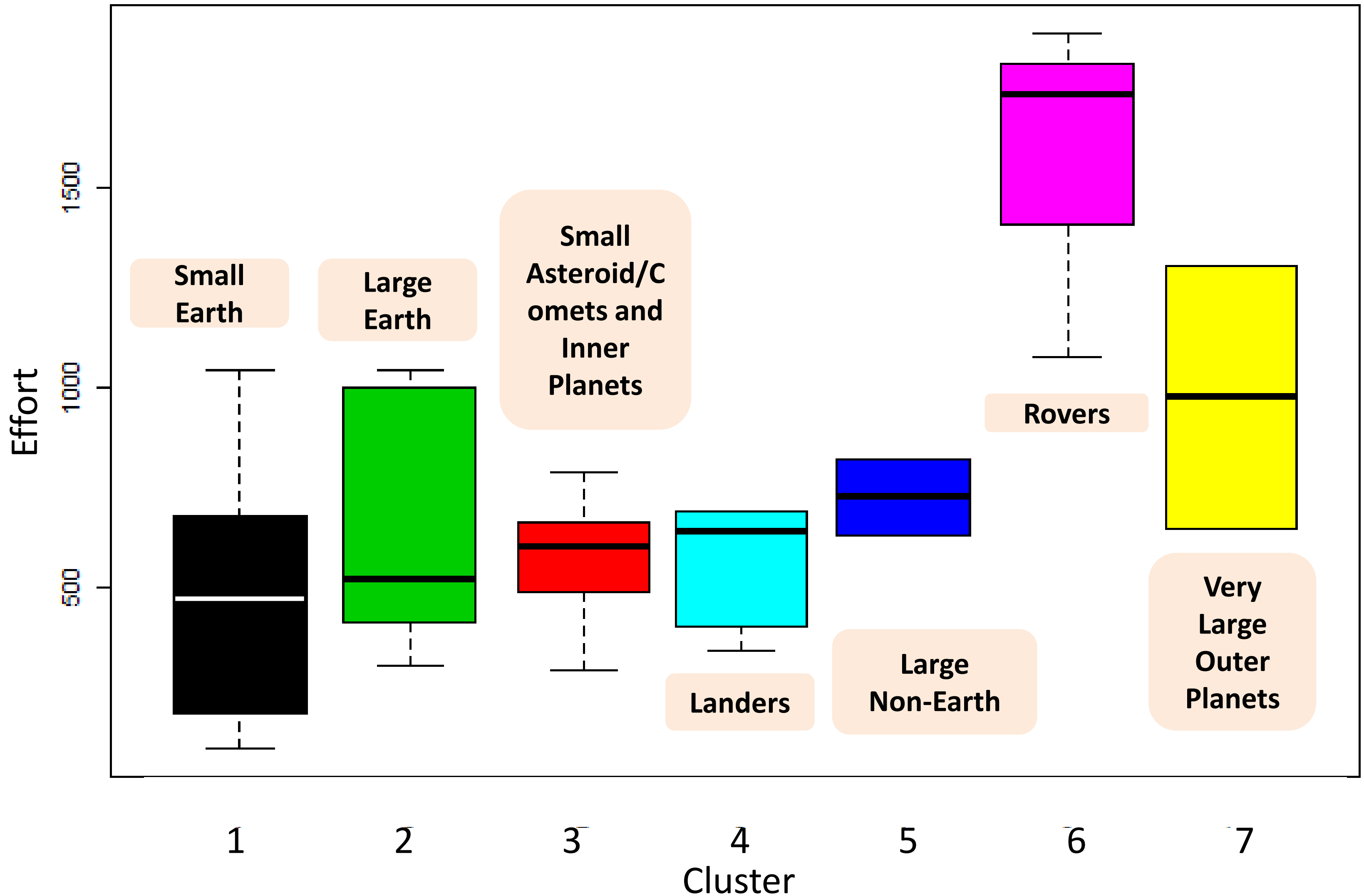
Clustering Analysis

By gradually increasing the granularity of our clusters, while maintaining robustness to avoid overfitting, we were able to find logical separation between groupings of missions



Number of Clusters	2	3	4	5	6	7	8

Reduced Cluster Effort Variation



Cluster Parameter Summary

Cluster	Mission Cost Median	Mission Cost Range	Software Inheritance	Destination	Mission Type	flight Computer Redundancy	Number of Instruments	Number of Deployabes	Development Work Months Median	Development Work Months Range
1	$321M	$170M - $500M	High-Very High	Earth	Orbiter	Single String	1 to 4	0 to 4	492	230 to 870
2	$824M	$420M - $1,250M	Medium to High	Earth & Inner Planets	Orbter	Dual String - Cold backup	2 to 6	2 to 8	603	340 to 790
3	$292M	$220M - $550M	Medium	Asteroid/Comets & Inner Planets	Orbiter/ Flyby	Dual String - Cold backup	2 to 7	0 to 3	525	450 to 1040
4	$548M	$630M - $820M	High-Very High	Inner Planet (Mars)	Lander	Dual String - Warm backup	4 to 5	2 to 3	728	630 to 820
5	$696M	$550M - $850M	High-Very High	Planets & Asteroids/Comet	Orbiter/ Flyby	Dual String - Cold backup	3 to 9	0 to 3	641	400 to 690
6	$1,123M	$420M - $2,600M	None-Low	Inner Planet (Mars)	Rover	Dual String - Warm backup	3 to 10	6 to 10	1735	1000 to 1890
7	$2680M	$2,300M - $3,000M	None-Low	Outer Planets	Orbiter/ Flyby	Dual String - Warm backup	11 to 12	4 to 8	978	650 to 1300

NASA Mission Clustering is More Logical

Mission	Effort	Destination	Type	Cluster
GEMS	100	Earth	Observatory	1
GLORY	133	Earth	Orbiter	1
GPM Core	1043	Earth	Orbiter	1
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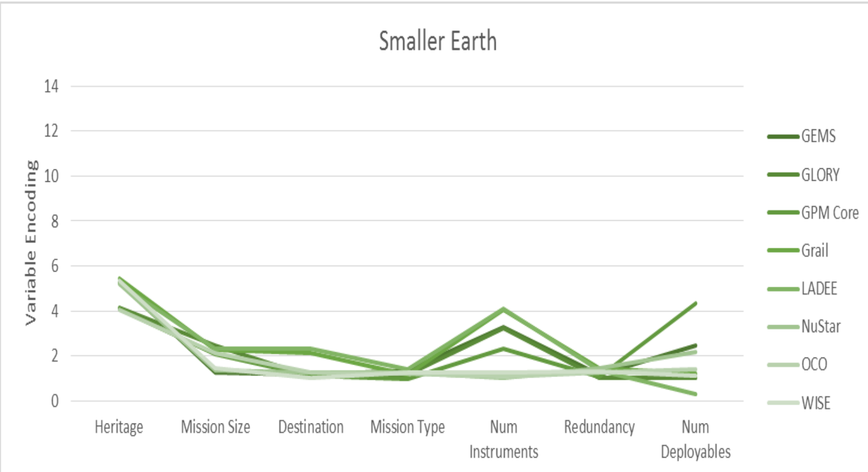
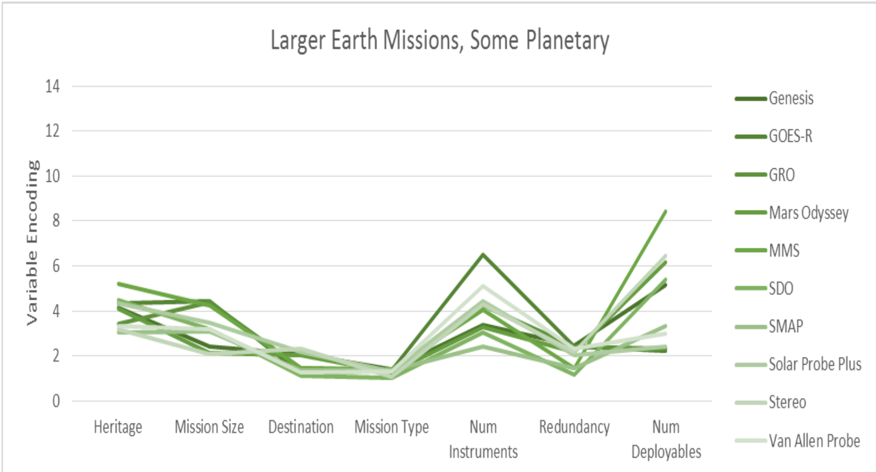
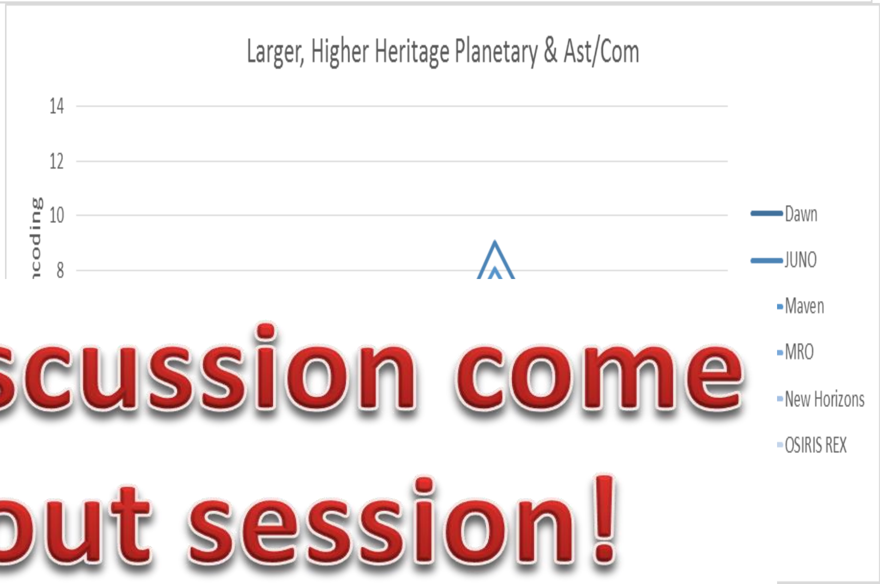
Reduced Cluster Parameter Variation







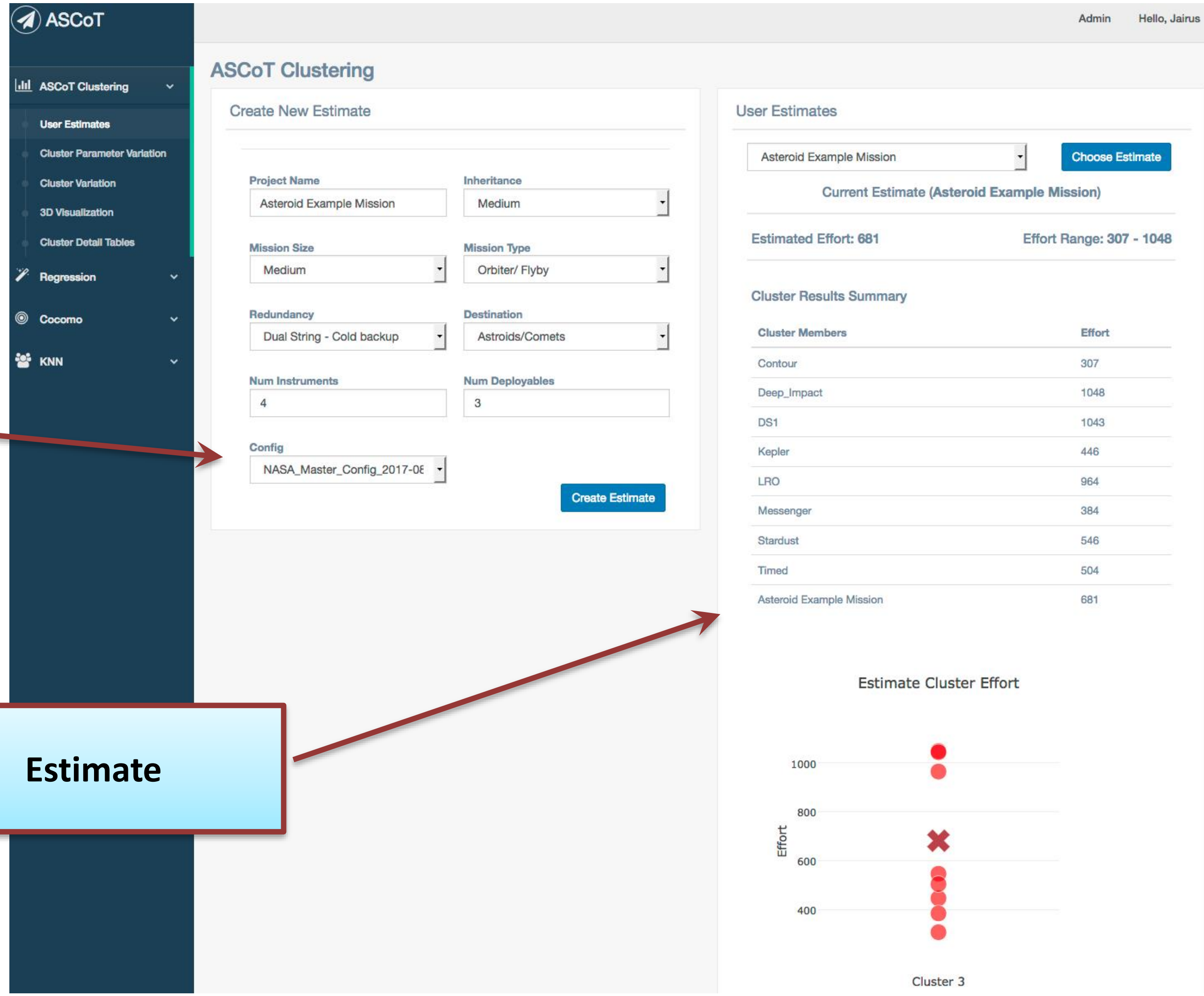
For detailed discussion come to the breakout session!

ASCoT Web Model : Analogy Cluster Model Main View

Left Hand Navigation Menu with Analysis Types

Model Inputs

Estimate



ASCoT Web Model:
Analogy Cluster Model Parameter View

Cluster Effort Months Result (Median)

Top graph compares the User Inputs vs Cluster members

1 Line per Mission in the Cluster plus 1 Line for User Inputs

Where lines overlap, User Inputs align with values for Missions in the Cluster

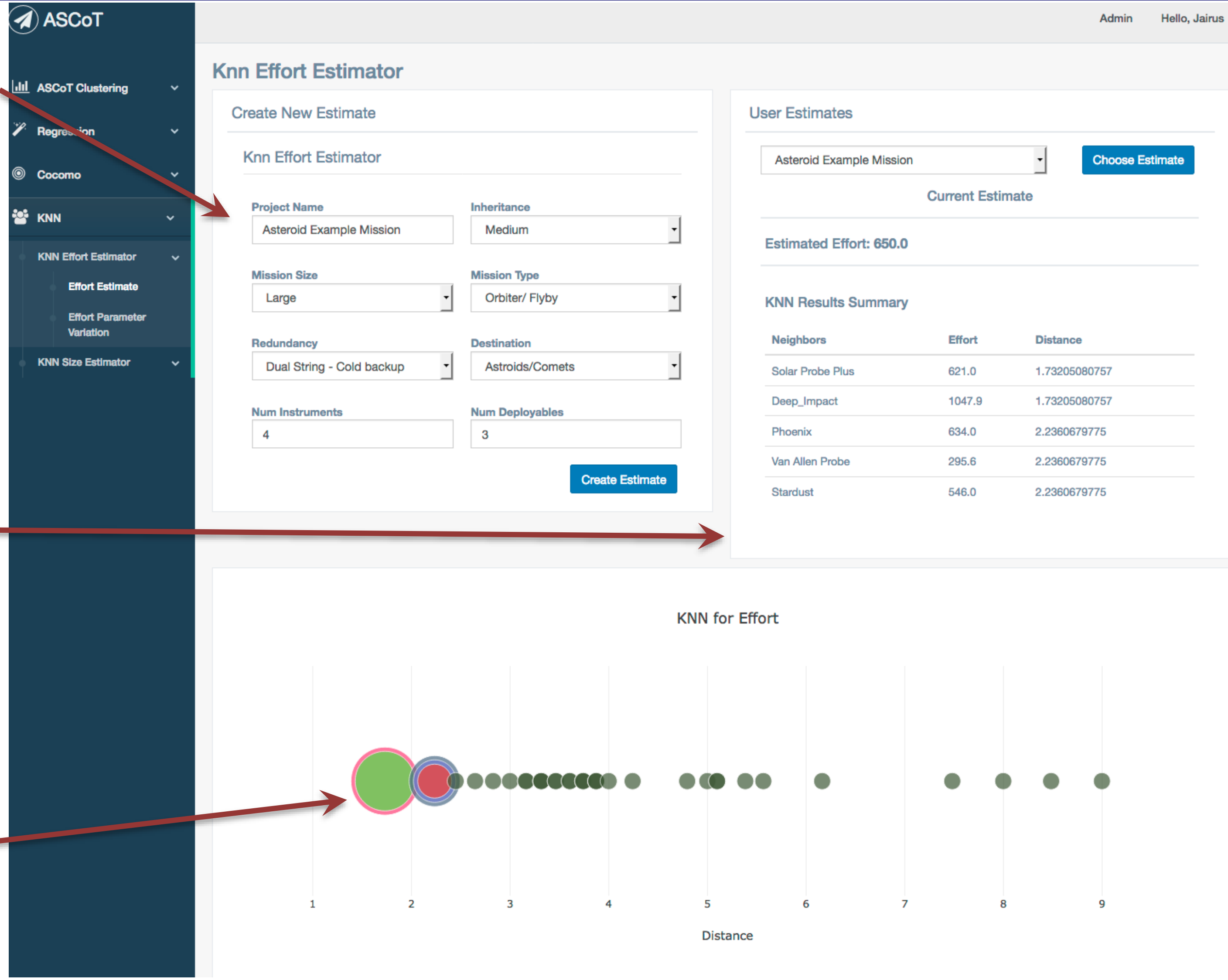
Other reference Cluster compared to User Inputs are less aligned

ASCoT Web Model:
KNN Model Main View

Model Inputs

Estimate

Results based on Euclidian distance



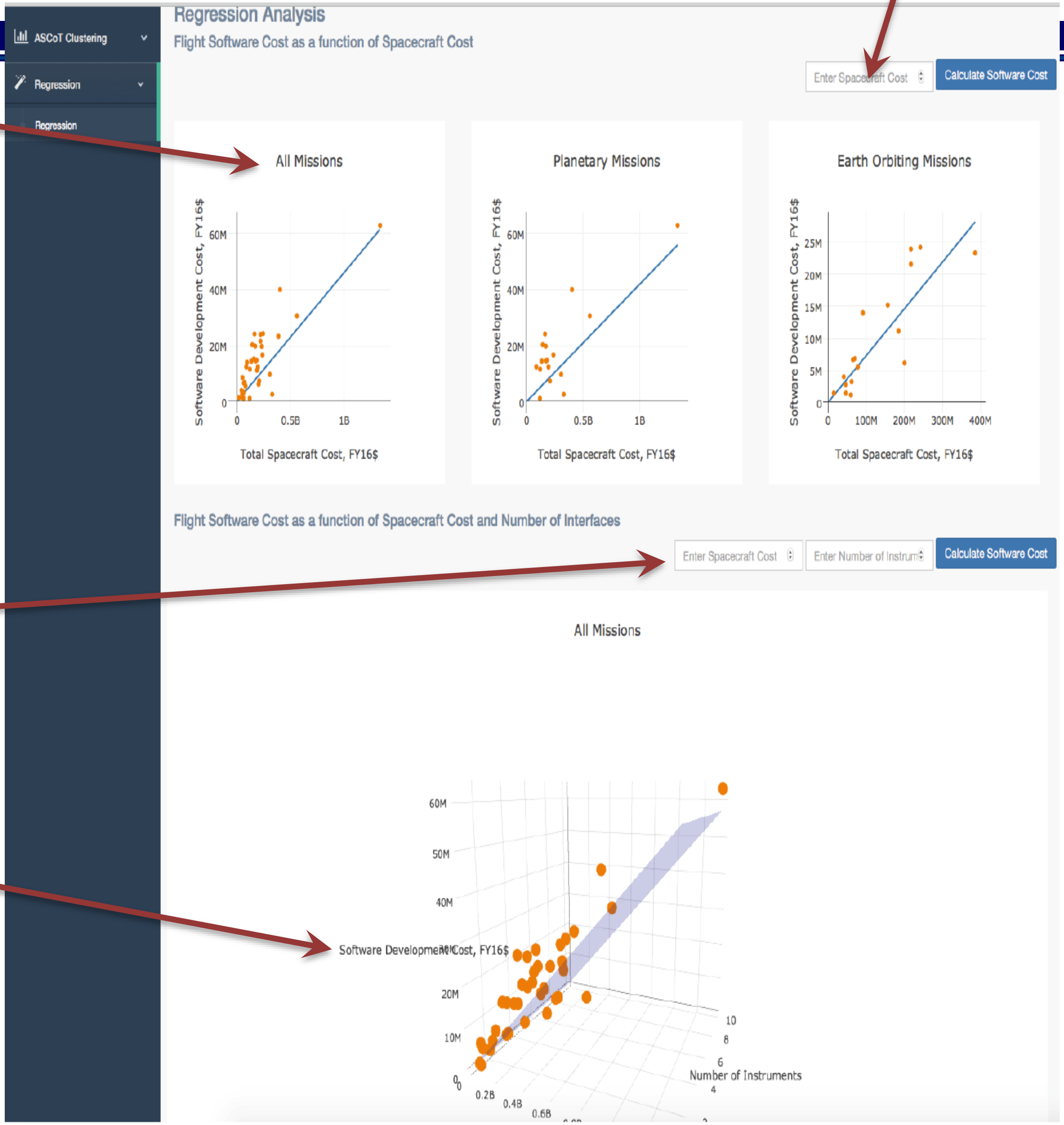
ASCoT Web Model: Cost Regression View

User Input of Total Spacecraft Cost

Regressions shown for "All Missions", "Planetary Missions", and "Earth Orbiting Missions"

Additional Regression includes Number of Instruments as input

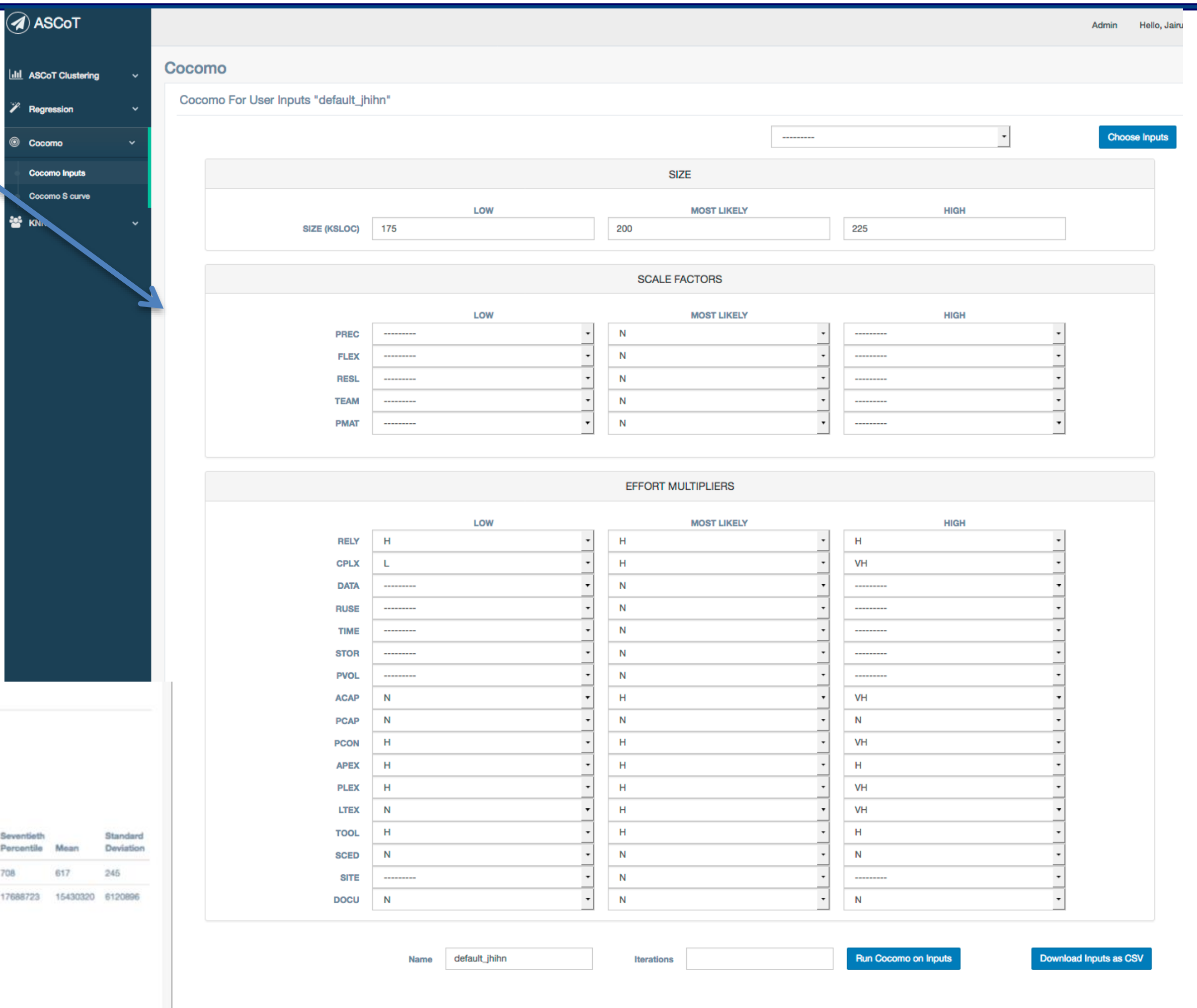
X-Axis = Number of Instruments
Y-Axis = Spacecraft Cost
Z-Axis = Software Dev Cost

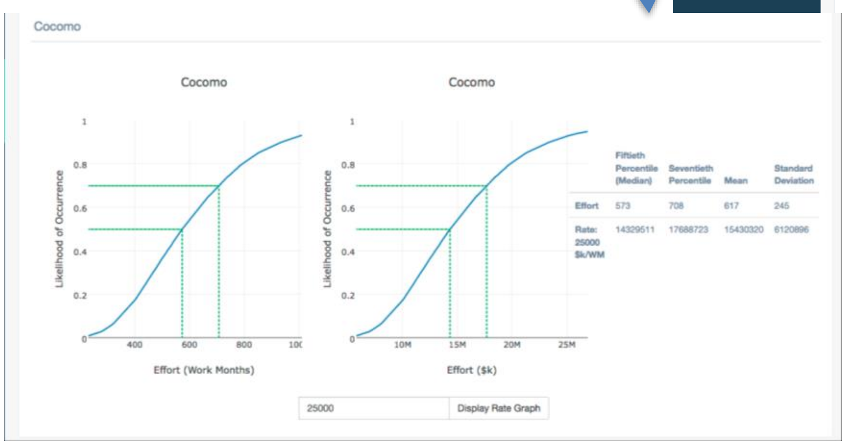


ASCoT Web Model: COCOMO II Model Main View

Standard COCOMO inputs with estimated effort and cost S-Curves

In next release will link analogy models as front-end to COCOMO II





ASCoT Break Out Session
mini-tutorial
and
more on what is under the hood

Back Up

Data Items Overview

Data Item	2017
Total development effort in work months	41
Flight Software Development Cost	43
Flight System Development Cost	43
Logical Lines of Code (LOC)	
Delivered LOC	51
Inherited LOC (Reused plus Modified	44
COCOMO Model inputs (See Appendix A for tge parameter definitions) - Translated from CADRe which has SEER model inputs becauase the SEER data items are very	19
Systems Parameters	
Mission Destination (Asteroid/Comets, Earth, Inner (planetary), Outer	51
Multiple element (probe, etc...)	51
Number of Instruments	51
Number of Deployables	51
Flight Computer Redundancy (Dual Warm, Dual Cold, Single String)	51
Software Reuse (Low, Medium, High)	44
Software Size (Small, Medium, Large, Very Large)	51

ASCoT Publications & Presentations

Publications: Conference

2. IEEE Aerospace
- Improving and Expanding NASA Software Estimation Methods, 2016 Aerospace Conference, Big Sky, Mt., March 2016.
- NASA Analogy Software Cost Model: A Web-Based Cost Analysis Tool, , 2017 Aerospace Conference, Big Sky, Mt., March 2017.

2. Automation in Software Engineering (ASE)
- Data Mining Methods and Cost Estimation Models: Why is it so hard to infuse new ideas? , Automation in Software Engineering 2015, Norman, Nebraska, Nov. 2015.

1. International Cost Estimation and Analysis Association (ICEAA)
- NASA Software Cost Estimation Model: An Analogy Based Estimation Method, 2015 International Cost Estimation and Analysis Association (ICEAA) Professional Development & Training Workshop, San Diego California, June 2015
- A Next Generation Software Cost Model, 2014 International Cost Estimation and Analysis Association (ICEAA) Professional Development & Training Workshop, Denver Colorado , June 2014.

Publications: Journal

1. **Empirical Software Engineering**
- Negative results for software effort Estimation, Empirical Software Engineering, Nov 2016. Menzies, Yang, Mathew, Boehm, Hihn

1. NASA Cost Symposium
- ASCoT R2: A web-based model of the NASA Analogy Software Costing Tool, Goodbye Excel", 2016 NASA Cost Symposium, NASA Glen Research Center, August. 2016. J. Hihn and J. Johnson
- NASA Software Cost Estimation Model: An Analogy Based Estimation Method. 2015 NASA Cost Symposium, NASA Ames Research Center, August 2015. J. Hihn and J. Johnson.
- A Next Generation Software Cost Model: A look under the Hood. 2014 NASA Cost Symposium, NASA Langley Research Center, August 2014. J. Hihn and J. Johnson.

2. COCOMO Workshop
- NASA Analogy Software Costing Tool-ASCoT, 31tst International Forum on COCOMO and System/Software Cost Modeling,USC, October 2016. J. Hihn & M. Saing
- Just How Good is COCOMO and Parametric Estimation?, , 29th International Forum on COCOMO and System/Software Cost Modeling, USC, October 2014. Hihn et al.

Effort Estimation with Data Mining Methods References

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"Kernel methods for software effort estimation" by E. Kocaguneli and T. Menzies and J. Keung. Empirical Software Engineering pages 1-24 2011

"On the Value of Ensemble Effort Estimation" by Kocaguneli, E. and Menzies, T. and Keung, J.. IEEE Transactions on Software Engineering 2011

"Exploring the Effort of General Software Project Activities with Data Mining" by Topi Haapio and Tim Menzies. International Journal of Software Engineering and Knowledge Engineering pages 725-753 2011

"Stable Rankings for Different Effort Models" by Tim Menzies and Omid Jalali and Jairus Hihn and Dan Baker and Karen Lum. Automated Software Engineering December 2010 . Available from http://menzies.us/pdf/10stable.pdf .

"Case-Based Reasoning for Reducing Software Development Effort" by Adam Brady and Tim Menzies and Oussama El-Rawas and Ekrem Kocaguneli and Jacky Keung. Journal of Software Engineering and Applications 2010 . Available from http://menzies.us/pdf/10w0.pdf .

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"Accurate Estimates Without Local Data?" by Tim Menzies and S. Williams and Oussama El-Rawas and D. Baker and B. Boehm and J. Hihn and K. Lum and R. Madachy. Software Process Improvement and Practice pages 213-225 July 2009 . Available from http://menzies.us/pdf/09nodata.pdf .

"Selecting Best Practices for Effort Estimation" by Menzies, Tim and Chen, Zhihao and Hihn, Jairus and Lum, Karen. IEEE Transactions on Software Engineering pages 883--895 doi = 10.1109/TSE.2006.114 issue = 11 2006