NASA Instrument Cost Model: NICM 10 Preview

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Jet Propulsion Laboratory
California Institute of Technology

Agenda

- Acknowledgements
- NICM Introduction
- NICM 10: Preview
  - Analytic solutions in System and Subsystem Tool – and Data Sheets
  - Isoquant visualization added to JCL Plots
  - Bayesian imputation improved with boundary conditions
  - Search Engine
    - Search by Model
    - Summary tables
    - Weighted averages using k-nearest neighbors

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NICM Stakeholders

- Sponsor: NASA HQ OCFO/SID
  - Special thank you to James Johnson
- Legacy Co-Sponsor: JPL Cost Estimation & Pricing Section
- Development Team
  - JPL Systems Modeling, Analysis & Architectures Group
  - JPL Engineering Cost Estimation Group
  - JPL Technical Division Experts
    - Science
    - Communications, Tracking, and Radar
    - Instruments and Science Data Systems
    - Mechanical Systems
  - Last but not least, all of the NASA Centers, Contractors, Universities and others who have built instruments and contribute data to NICM

NICM Team

NICM 10 Development Team

- Gary Ball
- Luther Beegle
- Justin Boland
- Kyle Brown
- Robert Cesarone
- Mike DiNicola
- **Sam Fleischer**
- Michael Fong
- **Melissa Hooke**
- **Joe Mrozinski**
- Al Nash
- Michael Saing
- **Sherry Stukes**
- Marc Walch

NICM Team

NICM 10 will be dedicated to our friend and colleague Gary Ball.

NICM Team

NICM Alumni/Advisors

- Daniel Belter
- Grace Chen
- Jerry Clark
- George Fox
- Hamid Habib-Agahi
- John Jack
- Leora Juster
- Eric Kwan
- Richard Levin
- Kamrooz Parchamazad
- John Pearson
- Matthew Ramirez
- Carrie Selski
- Cesar Sepulveda
- Louise Veilleux
- Keith Warfield
- Wayne Zimmerman
- Xiaoyan Zhou

NICM Consultants

- Ed Caro
- George Fraschetti
- Tom Fraschetti
- Dean Johnson
- Ken Klaasen
- Chris Paine
- Brian Sutin
- David Swenson

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NICM Introduction

- NICM is the ***NASA*** Instrument Cost Model**:**
  - Instrument Cost and Schedule (B/C/D) Estimating Tool Suite based off of previously flown space flight instruments across all of NASA.
  - Includes objective-input-based parametric cost and schedule models, cost and schedule analogy tools and JCL capabilities.
  - Models exist at both the total instrument and instrument subsystem levels.
  - Civil Servant copy includes all normalized data as well as a data Search Engine.
- Users:
  - All NASA Centers, Contractors, Universities etc.
  - Proposal Teams as well as by Proposal Evaluators.
  - Over 600 individuals have attended NICM Training sessions.
- For Free Training Contact: NICM@jpl.nasa.gov
- Download the NICM Excel file from:
  - www.oncedata.com (Civil and Contractor version)
  - www.software.nasa.gov (Contractor Version only)

A Brief NICM History

- NICM began collecting data in 2004
  - Foreshadowing: You'll notice our CERs are all in FY04. This is why.
  - NICM has collected and normalized data non-stop 2004-present.
  - Newly collected data feeds the updates to the NICM CERs.
- Trying to cram the highlights of 18 years of NICM history into 9 bullets:
  - NICM I: Released in 2006, with each tool in an individual workbook.
  - NICM II-III: A flood of new data pours in after the NICM I release.
  - NICM IV: In-situ instruments added. All tools combined into a single workbook.
  - NICM V: Schedule estimating and JCL added.
  - NICM VI: NICM-E capability and Cluster Tool added.
  - NICM VII: Telescope estimating capability added.
  - NICM VIII: Mission Class as a cost driver added.
  - NICM 9: Data Imputation Utilized, Multiple Build estimates introduced
  - NICM 10: To be released ~Fall 2022.

NICM Data

- Interviewing, Analyzing, Normalizing and Reviewing technical and cost Data is the heart and main strength of the NICM. Good models require good data.
- We are stringent when it comes to the quality, applicability and completeness of the data: before data is used for modeling, all records and normalization approaches are reviewed and blessed by both individuals who built the hardware as well as the multi-disciplinary NICM Team.

- **NICM 9 includes 299 Data Records**

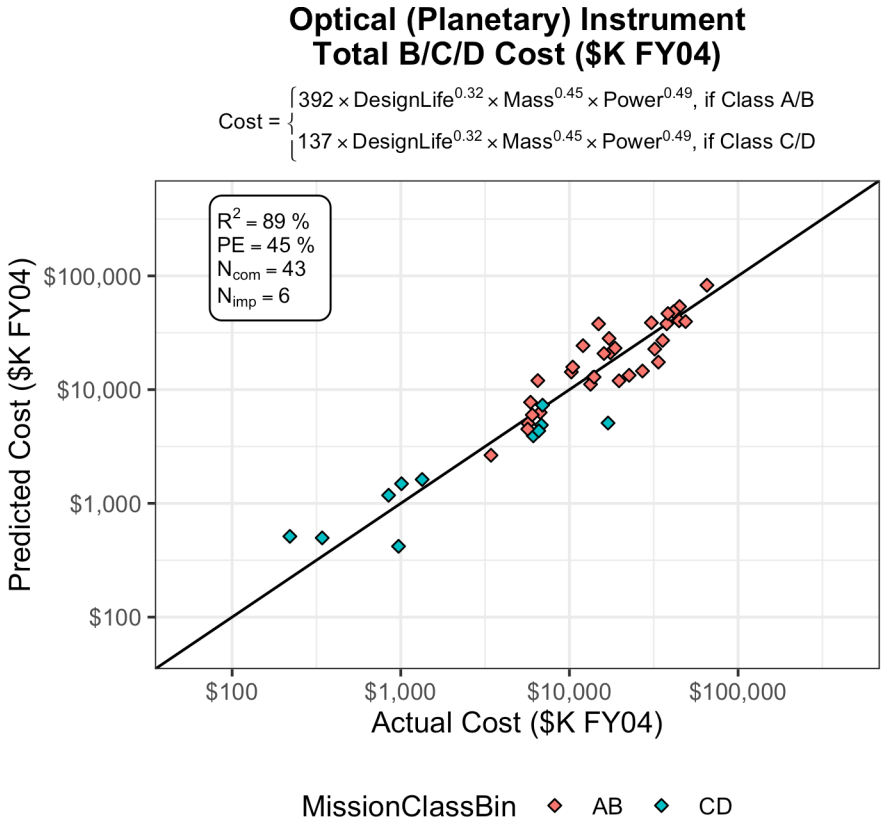
Modeling Methodology

- Cluster Analysis
  - Identifies Instrument Groupings from Attribute Values
  - Assesses Consistency of Groups with Instrument Types
- Principal Components Analysis
  - Finds Potential Cost Drivers from Instrument Attributes
  - Identifies NICM Data Outliers – Revisit data with technical experts
  - Finds separation in the data (i.e. clustering)
  - Addresses multi-collinearity in data for regression analysis
- Bootstrap Cross Validation
  - *Bootstrap*: Process for generating meaningful statistics without assuming asymptotic normality by resampling from the data with replacement. .
  - *Cross Validation*: Partitioning of data set into training and testing sets. Out-of-sample validation.
  - Bootstrap technique also used to perform statistical tests for regression analysis.
- Imputation: Allows for use of incomplete records.

Model Types

- NICM contains the following modeling types:
  - Cost Estimating Relationships (CERs).
  - Schedule Estimating Relationships (SERs).
- The CERs exist at two different levels:
  - The instrument System or Total Level.
  - The instrument Subsystem and Wrap Level.
- The SERs only produce a total instrument schedule (they do not provide subsystem schedules).

Example Model: Optical Planetary CER



Instruments used in this CER:			Imputed instruments used:
ALICE_Rosetta	CFI	CIRS	ALICE
CRISM	CRISP	CTX	IUVS
DLRE	IRAC	IRS	MDI
ISS	ITS	JunoCam	Ralph
LOLA	LORRI	LROC	SECCHI
M3	MARCI	MASCS	UVCS
MCS	MDIS	MICAS	
MIPS	MIR	MLA	
MOC-MO	MOLA-MO	MRI	
MSI	NavCam	NIR	
NIS	NLR	NSP	
ONC	PMIRR	TES_MO	
THEMIS	TLP	UVIS	
UVS - Juno	VIMS	VIS_LCROSS	
VSP			

Alternative form of equation:

$$Cost = 392\ DesignLife^{0.32}\ Mass^{0.45}\ Power^{0.49}\ exp(MissionClassBin)^{-1.05}$$

where MissionClassBin = 0 if Class A or B, & MissionClassBin = 1 if Class C or D

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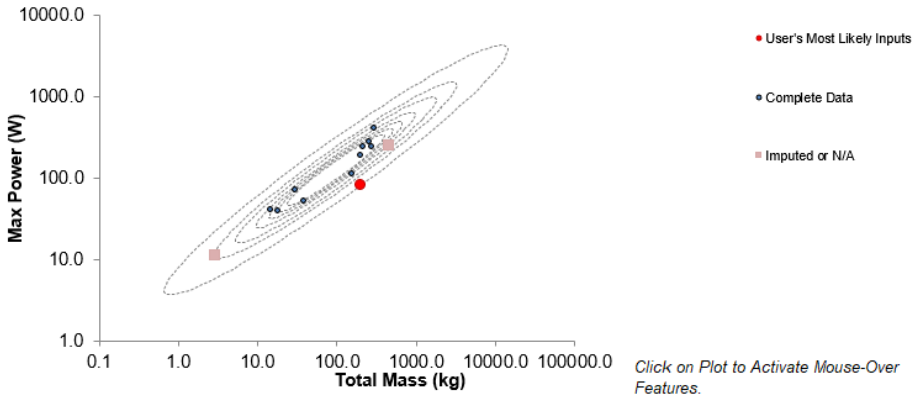
Analytic Solutions: Motivation

Here's a fresh version of NICM 9, with the inputs you'd see already entered when you download it.

Inputs

Instrument Name	
Costs in $K FY	2021
Instrument Type	Remote Sensing
Remote Sensing Type	Active Microwave
Environment	Planetary
Mission Class	B
Flagship Mission?	FALSE

	Minimum	Most Likely	Maximum
Total Mass (kg)		200	
Max Power (W)		80	
Number of Instruments		5	
Learning Slope%		90%	
Recurring Cost %		45%	



Click on Plot to Activate Mouse-Over Features.

Click on chart to activate mouse-over feature

X-axis	Total Mass (kg)
Y-axis	Max Power (W)

Monte Carlo # Iterations	1,000
Automatic Monte Carlo	On
NICM Help	Off

Copy Inputs to Search Engine

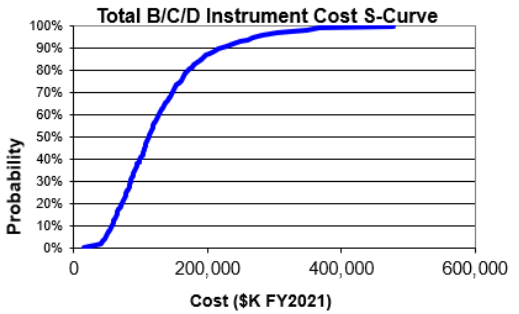
Copy Inputs to Subsystem

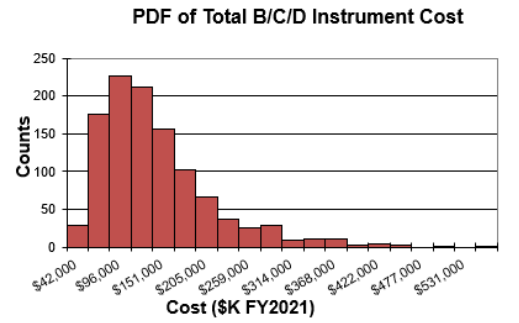
Generate Screenshots

NICM 9, November 2, 2020

Model Cost Estimates

Probability	30%	50%	70%
Total Instrument	$85,006	$112,202	$146,761
Management	$4,959	$7,427	$11,204
Sys. Engrg.	$5,392	$7,868	$11,652
Prod. Assurance	$3,055	$4,729	$7,453
I & T	$6,827	$10,406	$16,453
Total Sensor	$64,773	$81,772	$99,998





Multipe Builds	30%	50%	70%
1st Unit	$85,006	$112,202	$146,761
2nd Unit	$34,428	$45,442	$59,438
3rd Unit	$32,370	$42,726	$55,885
4th Unit	$30,985	$40,898	$53,494
5th Unit	$29,951	$39,534	$51,710
TOTAL ALL UNITS	$212,740	$280,800	$367,289

Analytic Solutions: Motivation

What happens when I change the 200 kg total mass to…. 200 kg?

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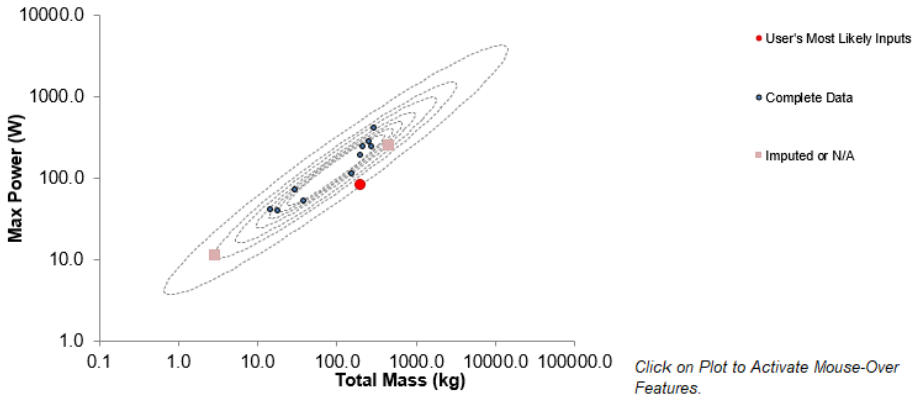

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Click on chart to activate mouse-over feature

X-axis	Total Mass (kg)
Y-axis	Max Power (W)

Monte Carlo # Iterations	1,000
Automatic Monte Carlo	On
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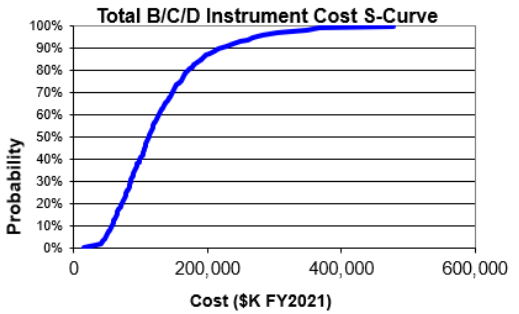

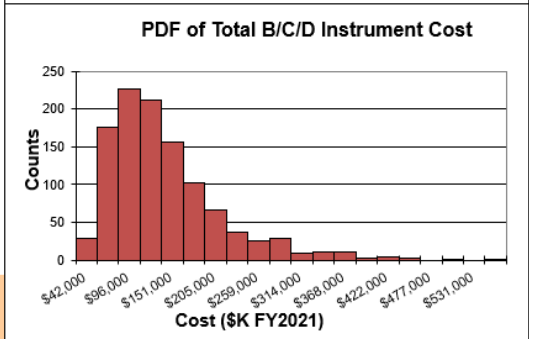

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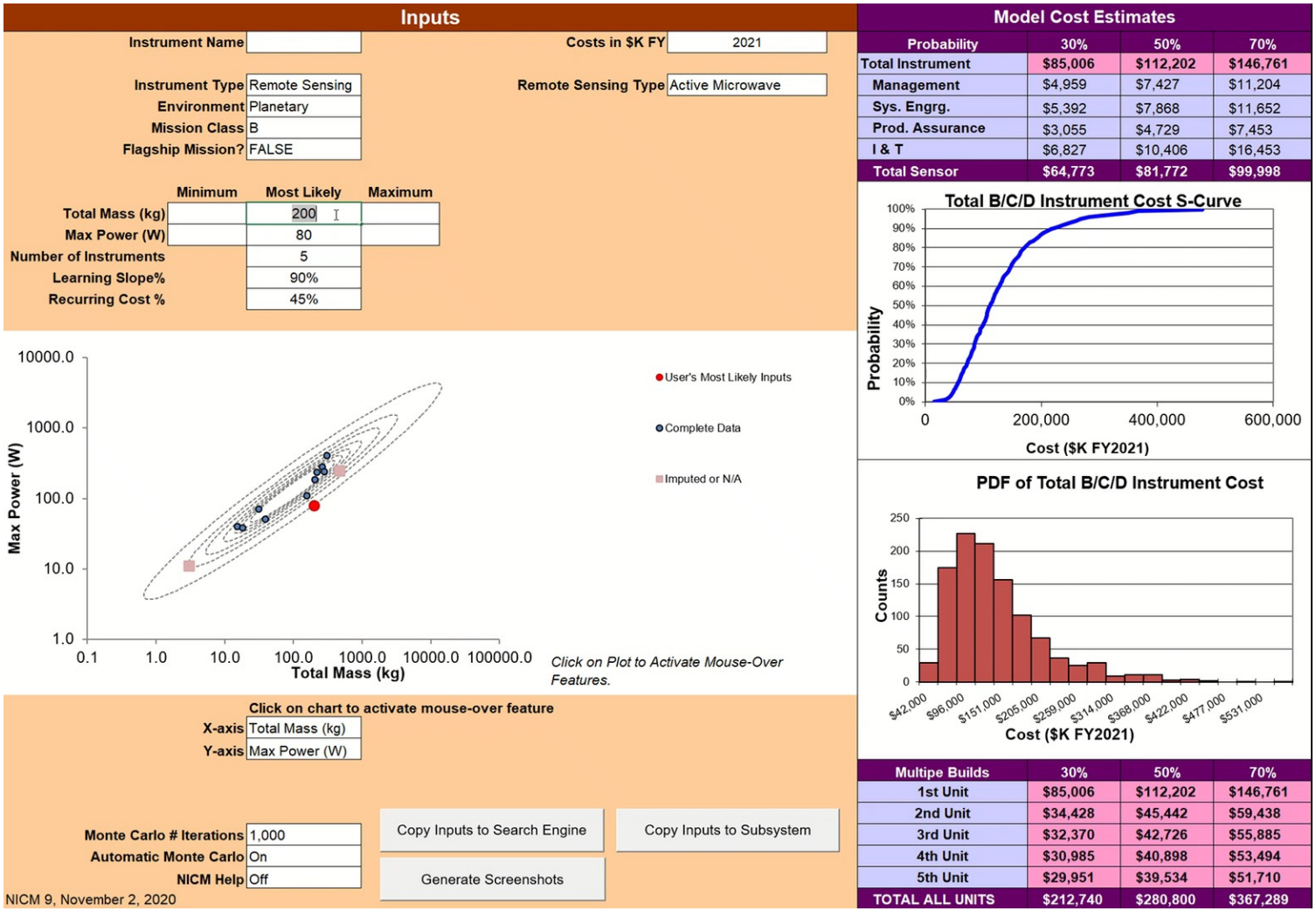
Analytic Solutions: Motivation

What happens when I change the 200 kg total mass to…. 200 kg? And, what happens if I hit recalculate a few times after that?



Analytic Solutions: Motivation

We see for the same inputs, for 1000 Monte Carlo iterations, we can have a hard time reproducing our outputs.

Inputs

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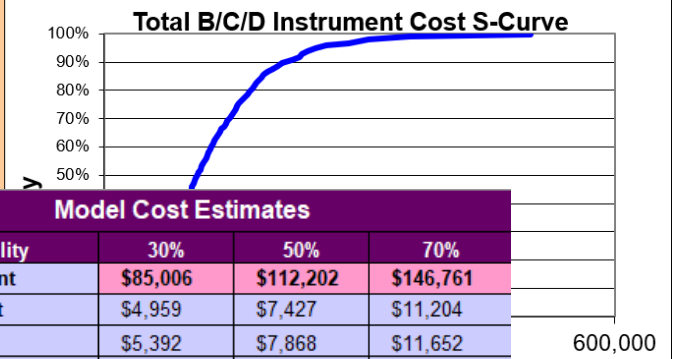
Instrument Type	Remote Sensing	Remote Sensing Type	Active Microwave
Environment	Planetary		
Mission Class	B		
Flagship Mission?	FALSE		

	Minimum	Most Likely	Maximum
Total Mass (kg)		200	
Max Power (W)		80	
Number of Instruments		5	
Learning Slope%		90%	
Recurring Cost %		45%	

Model Cost Estimates

Probability	30%	50%	70%
Total Instrument	$83,768	$109,984	$146,867
Management	$4,862	$7,326	$10,764
Sys. Engrg.	$5,280	$7,750	$11,145
Prod. Assurance	$2,993	$4,722	$7,179
I & T	$6,675	$10,484	$15,839
Total Sensor	$63,959	$79,702	$101,941



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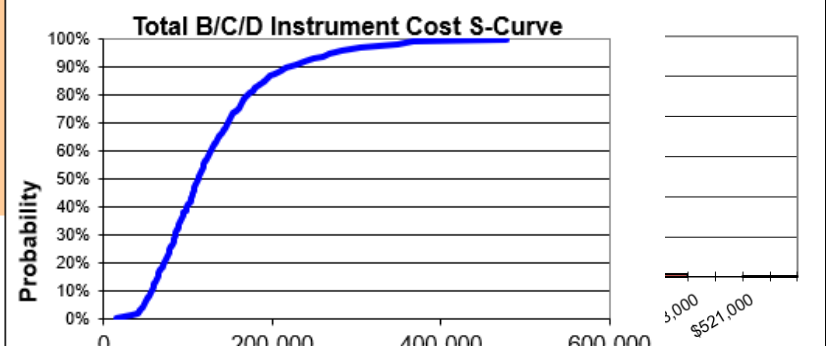

• User's Most Likely Inputs

Analytic Solutions: Repeatable Solution

In NICM 10, *when only most likely inputs are entered*, the Monte Carlo is turned off automatically and a *REPEATABLE* analytic solution is provided.

Inputs

Instrument Name	User's Instrument
Costs in $K FY	2021
Instrument Type	Remote Sensing
Remote Sensing Type	Active Microwave
Environment	Planetary
Mission Class	B
Flagship Mission?	FALSE

	Minimum	Most Likely	Maximum
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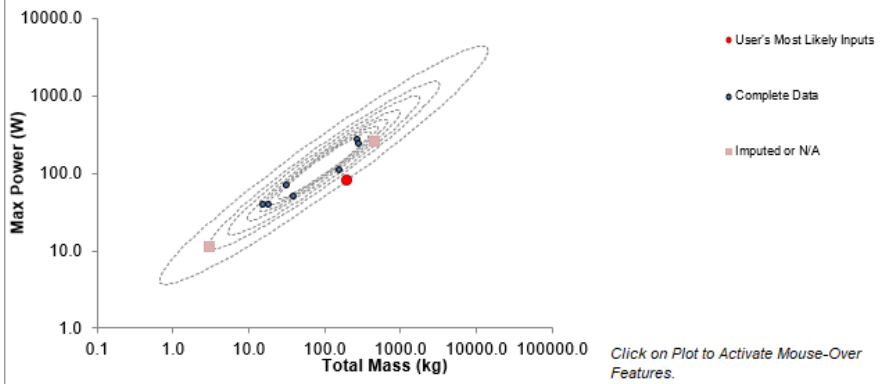


Click on chart to activate mouse-over feature

X-axis	Total Mass (kg)
Y-axis	Max Power (W)

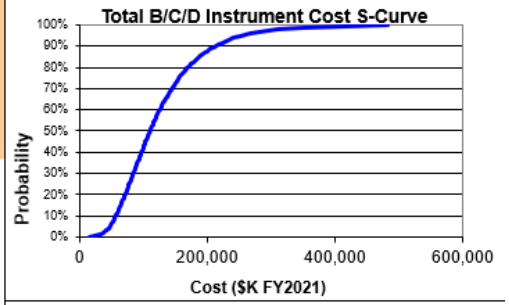
Monte Carlo # Iterations	1,000
Analytic or Monte Carlo?	Analytic
Automatic Mode	On
NICM Help	Off

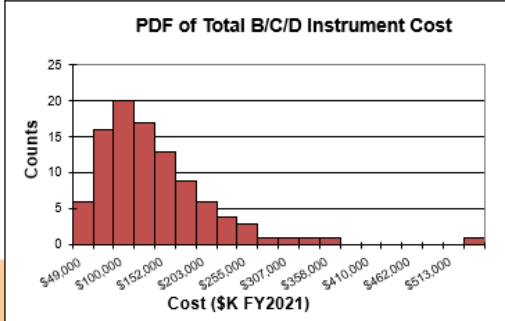
Copy Inputs to Search Engine | Copy Inputs to Subsystem | Generate Screenshots

NICM 10 Draft - April 2022

Model Cost Estimates

Probability	30%	50%	70%
Total Instrument	$84,587	$110,660	$144,770
Management	$4,859	$7,210	$10,694
Sys. Engrg.	$5,217	$7,658	$11,235
Prod. Assurance	$3,024	$4,609	$7,019
I & T	$6,657	$10,203	$15,626
Total Sensor	$64,831	$80,980	$100,197





Multipe Builds	30%	50%	70%
1st Unit	$84,587	$110,660	$144,770
2nd Unit	$34,258	$44,817	$58,632
3rd Unit	$32,210	$42,139	$55,127
4th Unit	$30,832	$40,336	$52,769
5th Unit	$29,804	$38,990	$51,009
TOTAL ALL UNITS	$211,691	$276,942	$362,306

Analytic Solutions: Repeatable Solution

To say it differently: The inputs seen below will always yield the outputs seen below – again noting that the min and max inputs are not used.

Inputs

Instrument Name	User's Instrument	Costs in $K FY	2021
Instrument Type	Remote Sensing	Remote Sensing Type	Active Microwave
Environment	Planetary		
Mission Class	B		
Flagship Mission?	FALSE		

	Minimum	Most Likely	Maximum
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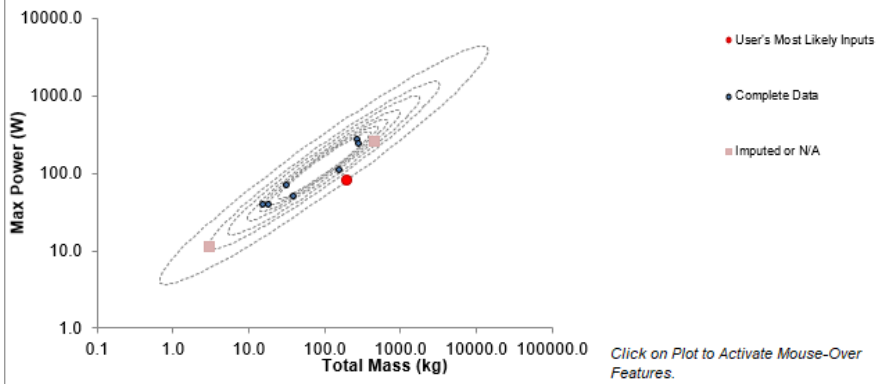

Click on chart to activate mouse-over feature

X-axis	Total Mass (kg)
Y-axis	Max Power (W)

Monte Carlo # Iterations	1,000
Analytic or Monte Carlo?	Analytic
Automatic Mode	On
NICM Help	Off

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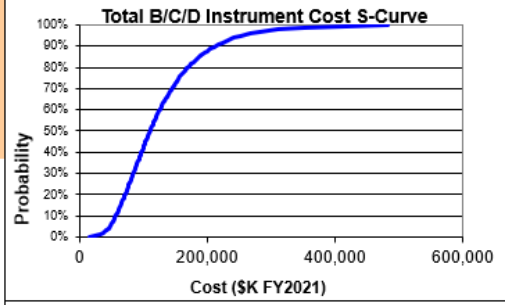

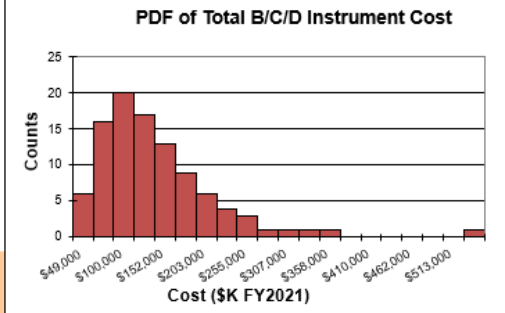

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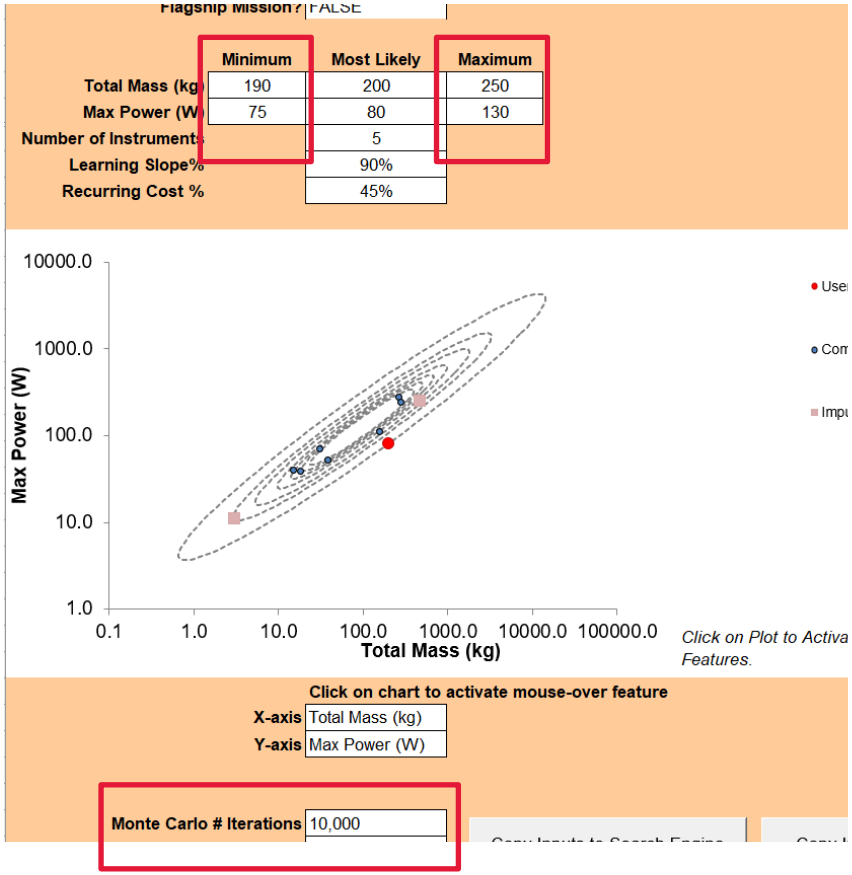
5th Unit	$29,804	$38,990	$51,009
TOTAL ALL UNITS	$211,691	$276,942	$362,306

Analytic Solutions: When Not Available.

When a Minimum or Maximum input is entered, the tool switches back to Monte Carlo Mode. To better converge towards a repeatable solution, increase the default Monte Carlo iterations from 1,000 to 10,000.



Analytic Solutions in the Subsystem Tool

The Subsystem will switch between an Analytic Solution and Monte Carlo solution in the same fashion as the System Tool.

Analytic Solutions in the Instrument Data Sheets

The NICM 10 Instrument Datasheets will show the System and Subsystem Analytic Solutions for all applicable CERs, allowing for comparison between Instrument Actual costs and the analytic cost estimates of the two tools.

Development Cost (Phases B/C/D) $K FY2021								
			Subsystem Tool Estimates			System Tool Estimates		
		Actuals	30%	50%	70%	30%	50%	70%
	TOTAL Development Cost	$33,333	$27,679	$39,314	$37,139	$28,532	$35,301	$43,675
	Management Cost	$2,222	$1,344	$1,961	$3,027	$1,691	$2,429	$3,488
	Systems Engineering Cost	$2,222	$1,648	$2,395	$3,488	$1,945	$2,774	$3,954
	Product Assurance Cost	$1,111	$687	$1,069	$1,560	$898	$1,314	$1,922
	Integration & Test Cost	$2,222	$1,494	$2,249	$3,500	$1,947	$2,864	$4,210
	Other Cost							
	Total Sensor Cost	$25,556	$22,506	$31,641	$25,564	$22,051	$25,919	$30,101
	Optics Cost	$7,777						
	Telescope Cost							
	Antenna Cost		$5,284	$6,574	$8,343			
	Mechanical/Structure Cost	$4,444	$6,316	$9,322	$6,316			
	Thermal/Fluid Cost	$2,222	$4,918	$7,432	$4,918			
	Cryocooler Cost							
	Electronics Cost	$10,111	$5,210	$7,206	$5,210			
	Detectors Cost							
	Software Cost	$1,002	$777	$1,108	$777			
	Other Subsystem Cost							

* “Actual data” in this example = dummy data.

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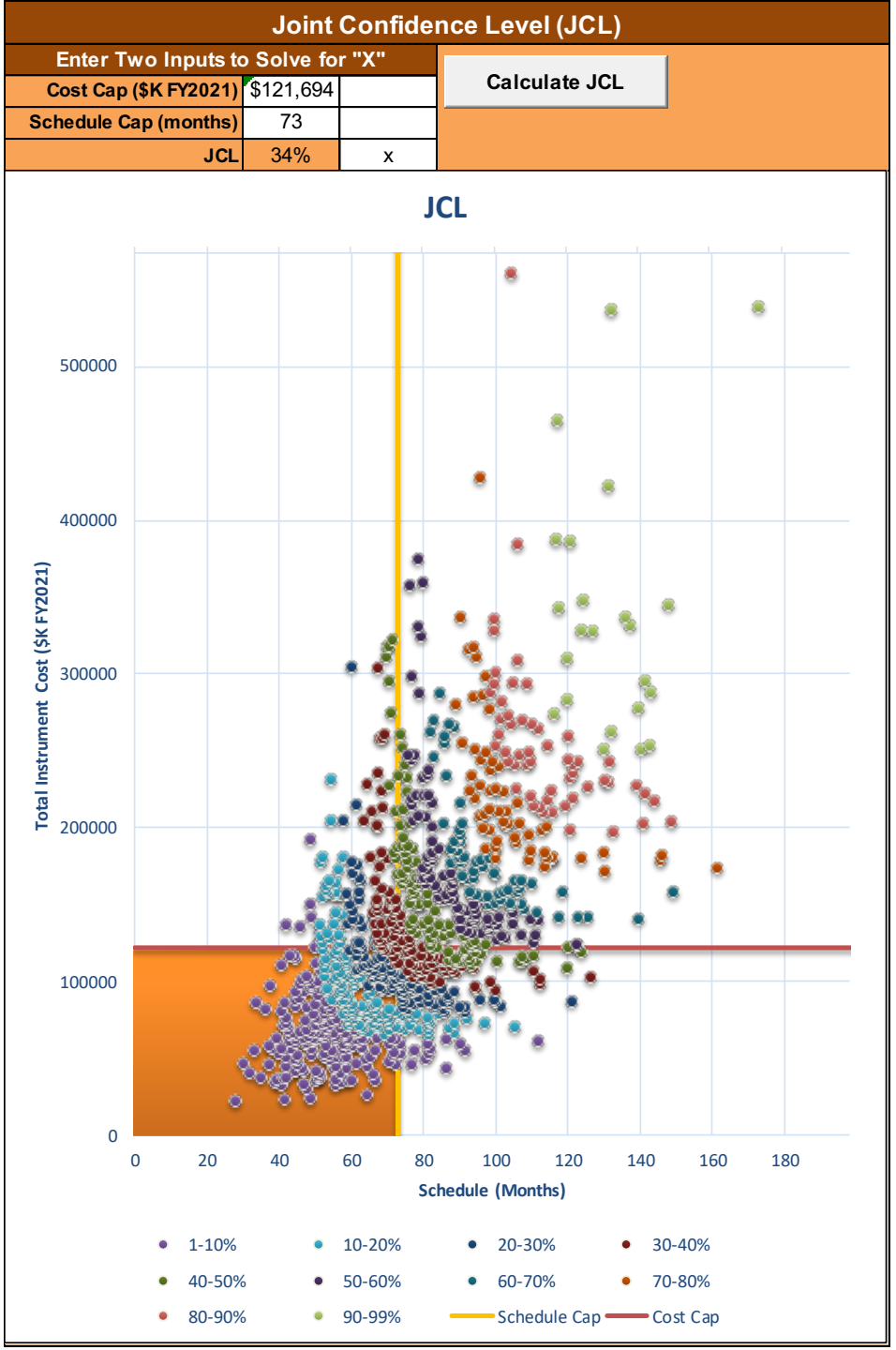
Isoquant Visualization Added to JCL Plots

- The Isoquants (or indifference curves or frontier curves if you prefer) and represented by color coding simulated cost/schedule pairs according to which JCL percentage band they fall into: 1-10%, 10-20%, 20-30%, and so forth…
- Beware of pitfalls: cost and schedule can not be simply trade as isoquants might seem to indicate…



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- Acknowledgements
- NICM Introduction
- NICM 10: Preview
  - Analytic solutions in System and Subsystem Tool – and Data Sheets
  - Isoquant visualization added to JCL Plots
  - **Bayesian imputation improved with boundary conditions**
  - Search Engine
    - Search by Model
    - Summary tables
    - Weighted averages using k-nearest neighbors

Bayesian Imputation Improved with Boundary Conditions

Recall from our last Symposium presentation:

"***Data imputation*** is a statistical method used to handle missing data in a dataset by probabilistically filling a data observation's missing value(s) based on 1) the partial data that is available for that data observation and 2) the completed observations (those not missing any values) in the dataset."

Bayesian Imputation Improved with Boundary Conditions

- Using data imputation, the NICM team was able to make improvements (green) to the following System Tool CERs in NICM 9:

CER	Complete Records	Imputed Records	V8.5 R^2	V9 R^2	V8.5 PE	V9 PE
Optical Planetary	43	6	89%	89%	48%	45%
Optical Earth Orbiting	35	10	85%	85%	48%	42%
Passive Microwave	12	2	86%	86%	37%	34%
Fields	12	2	74%	74%	44%	41%
Particles Planetary	30	7	60%	62%	52%	47%
Particles Earth Orbiting	24	3	77%	77%	53%	53%
Body Mounted	13	1	72%	72%	64%	62%
Arm/Mast Mounted	12	1	59%	60%	52%	50%

Bayesian Imputation Improved with Boundary Conditions

- In NICM 10, the Bayesian Imputation will be improved further as we add boundary conditions to constrain the imputed distributions using secondary data previously collected, including:
  - System tool
  - - Average power (lower bound)
  - - Mission Payload total cost (upper bound)
  - - Total cost for a multiple unit total cost (upper bound)
  - - Total instrument cost of a “modified build” instrument (lower bound)
  - - Total instrument cost of a Faster Better Cheaper instrument (lower bound)
  - - Total instrument cost missing small amount of foreign contribution (lower bound)

  - Subsystem tool
  - - Total cost minus any other known subsystem costs (upper)
  - - Total mass minus any other known subsystem masses (upper)

(By the way)

In NICM 10, we plan on relocating the cost “Notes” section in the NICM datasheets to make way to display a representative portion of the imputed cost distribution for any imputed instrument cost.

Development Cost (Phases B/C/D) $K FY2021								
			Subsystem Tool Estimates			System Tool Estimates			
		Actuals	30%	50%	70%	30%	50%	70%	Notes
	TOTAL Development Cost	$33,333	$27,679	$39,314	$37,139	$28,532	$35,301	$43,675	
	Management Cost	$2,222	$1,344	$1,961	$3,027	$1,691	$2,429	$3,488	
	Systems Engineering Cost	$2,222	$1,648	$2,395	$3,488	$1,945	$2,774	$3,954	
	Product Assurance Cost	$1,111	$687	$1,069	$1,560	$898	$1,314	$1,922	
	Integration & Test Cost	$2,222	$1,494	$2,249	$3,500	$1,947	$2,864	$4,210	
	Other Cost								
	Total Sensor Cost	$25,556	$22,506	$31,641	$25,564	$22,051	$25,919	$30,101	
	Optics Cost	$7,777							
	Telescope Cost								
	Antenna Cost		$5,284	$6,574	$8,343				
	Mechanical/Structure Cost	$4,444	$6,316	$9,322	$6,316				
	Thermal/Fluid Cost	$2,222	$4,918	$7,432	$4,918				
	Cryocooler Cost								
	Electronics Cost	$10,111	$5,210	$7,206	$5,210				
	Detectors Cost								
	Software Cost	$1,002	$777	$1,108	$777				
	Other Subsystem Cost								

* “Actual data” in this example = dummy data.

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    - **Search by Model**
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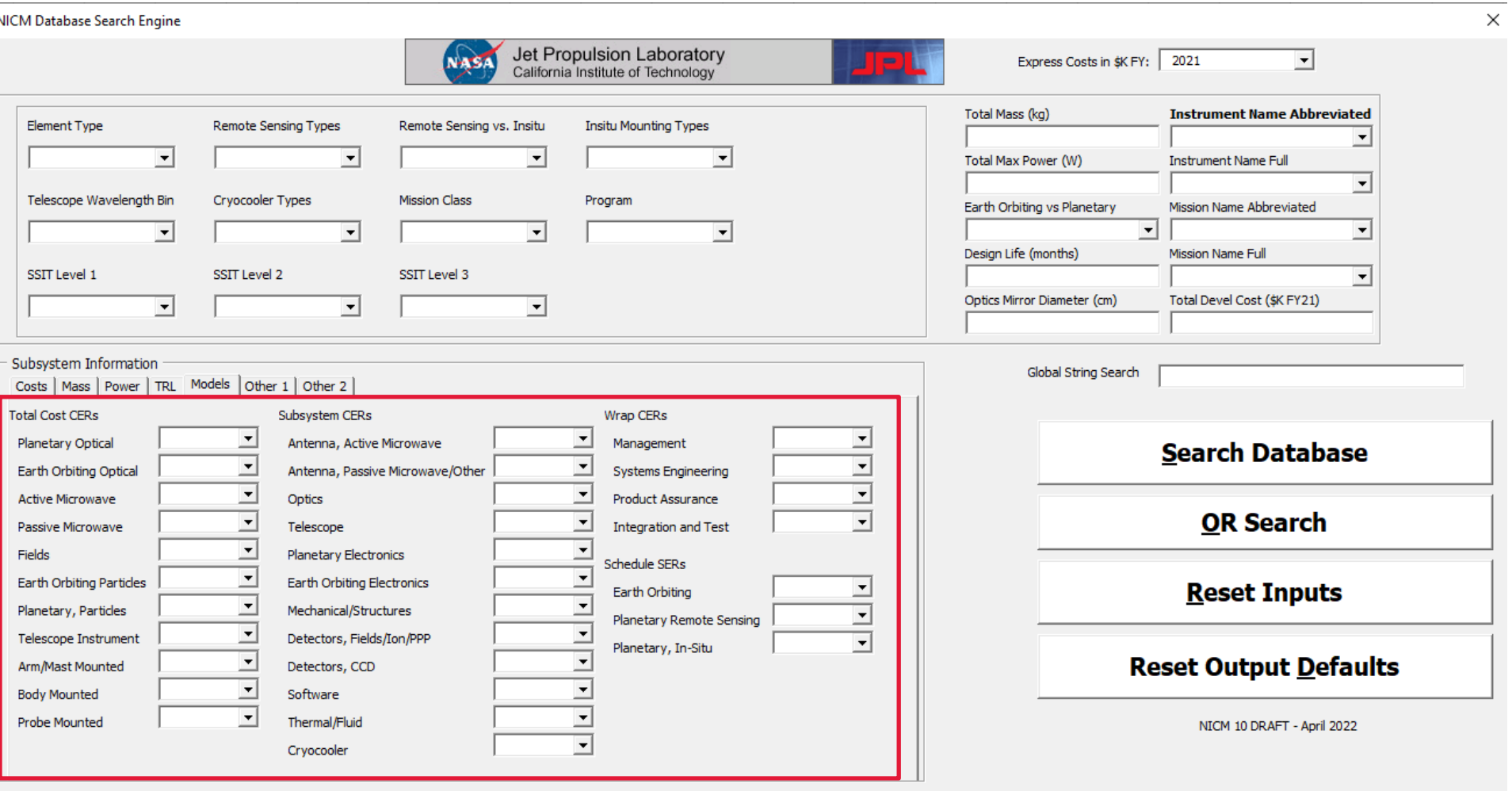
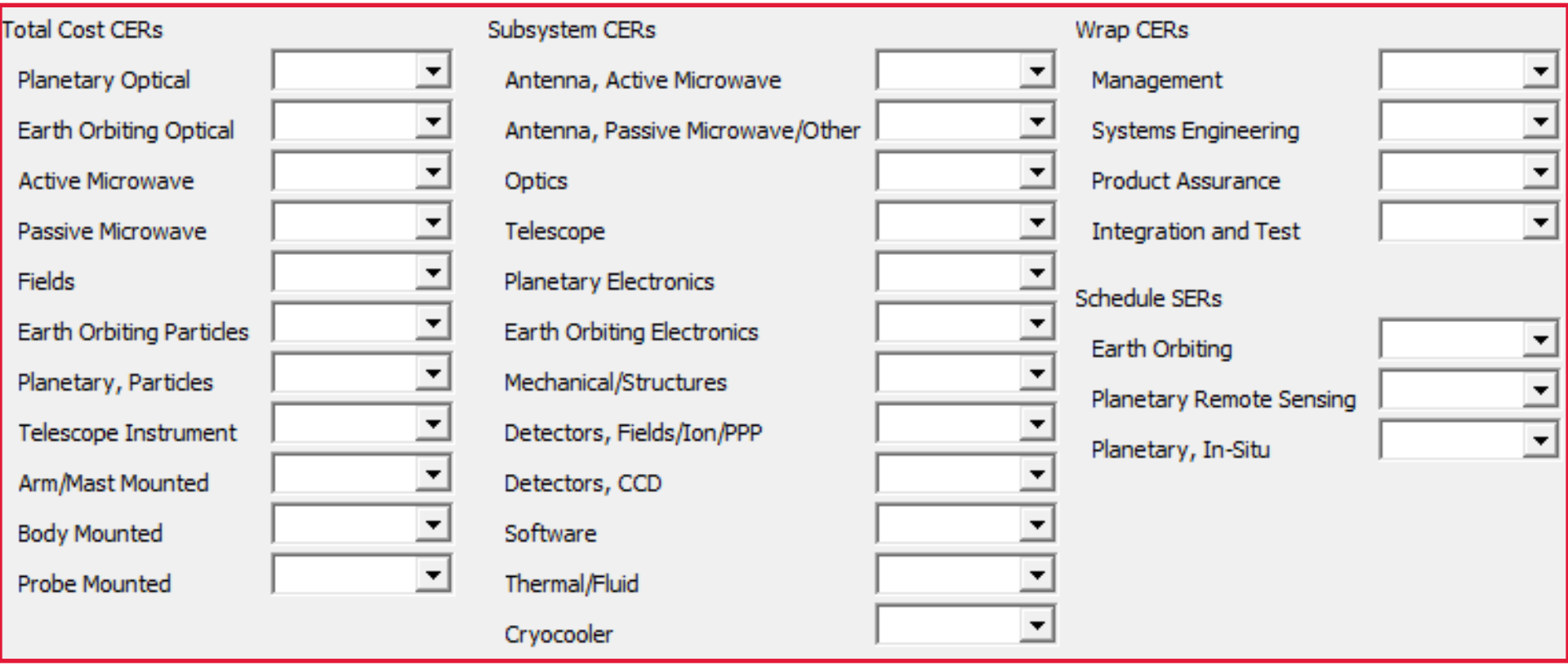
Search Engine: Search by Model

- A new section called “Models” has been added to the Search Engine.
- Let’s Zoom in on the red box…



Search Engine: Search by Model

- This section allows the user to quickly search for all Instruments used in a particular CER, and to perform sub-searches within those sets.



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Search Engine: Summary Tables

- Below the usual Search Engine results, NICM 10 will generate a simple summary table.
- We would like to hear what else you'd like to see in this automatic summary table.
- NICM@jpl.nasa.gov

Instrument Name Abbreviated	Instrument Type	Total Mass (kg)	Total Max Power (W)
APS-Glory	Optical	24.72	7.04
CERES	Optical	34.71	28.70
CERES-SuomiNPP	Optical	48.33	28.72
CIRS	Optical	7.52	22.12
CRISM	Optical	25.76	35.72
CRISP	Optical	26.02	31.74
FUV	Optical	7.22	20.29
FUV_ICON	Optical	28.63	9.02
HRI_Deep_Impact	Optical	5.01	49.80
IRAC	Optical	16.06	6.92
IRS	Optical	5.19	51.25
ISS	Optical	26.92	54.78
LRI	Optical		1
MDI	Optical		8
MIGHTI	Optical		7
MIPS	Optical		3
MOLA MGS	Optical	1.04	4.75
NOMAD	Optical	6.39	38.26
PFS	Optical	32.48	34.52
PMIRR	Optical	28.60	33.42
SOFIE	Optical	16.61	22.16
TIDI	Optical	11.74	18.97
TIM_Glory	Optical	23.43	23.52
TOMS	Optical	26.88	56.29
TRACE	Optical	50.92	53.40
VIMS	Optical	6.33	5.44
VIRS	Optical	9.62	6.74

Random Numbers, not actual data.

SUMMARY DATA	Instrument Type	Total Mass (kg)	Total Max Power (W)
Average:		20.11	27.79
Minimum:		1.04	4.75
Maximum:		50.92	59.67

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Search Engine: Weighted Averages Using kNN

- The kNN algorithm you have heard about many times from both ASCoT and COMPACT is now utilized in NICM as well.
- In addition to the simple average shown in the summary table, the NICM 10 Search Engine will now include an interface to determine weighted averages using kNN.

Search Engine: Weighted Averages Using kNN

- Below the summary Table, you will see the new kNN Estimates Inputs area. Supplying an input here will trigger the code to sort the Search Engine results according to the kNN algorithm, and subsequently display the kNN weighted average for all numeric non-inputs.

Instrument Name Abbreviated	Instrument Type	Total Mass (kg)	Total Max Power (W)
APS-Glory	Optical	24.72	7.04
CERES	Optical	34.71	28.70
CERES-SuomiNPP	Optical	48.33	28.72
CIRS	Optical	7.52	22.12
CRISM	Optical	25.76	35.72
CRISP	Optical	26.02	31.74
FUV	Optical	7.22	20.29
FUV_ICON	Optical	28.63	9.02
HRI_Deep_Impact	Optical	5.01	49.80
IRAC	Optical	16.06	6.92
IRS	Optical	5.19	51.25
ISS	Optical	26.92	54.78
LRI	Optical	40.01	9.41
MDI	Optical		58
MIGHTI	Optical		67
MIPS	Optical		13
MOLA MGS	Optical		75
NOMAD	Optical	6.39	38.26
PFS	Optical	32.48	34.52
PMIRR	Optical	28.60	33.42
SOFIE	Optical	16.61	22.16
TIDI	Optical	11.74	18.97
TIM_Glory	Optical	23.43	23.52
TOMS	Optical	26.88	56.29
TRACE	Optical	50.92	53.40
VIMS	Optical	6.33	5.44
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Random Numbers, not actual data.

SUMMARY DATA	Instrument Type	Total Mass (kg)	Total Max Power (W)
Average:		20.11	27.79
Minimum:		1.04	4.75
Maximum:		50.92	59.67

kNN Estimate Inputs:	Instrument Type	Total Mass (kg)	Total Max Power (W)

Search Engine: Weighted Averages Using kNN

- As soon as an input is entered, the code runs and you'll see the Search Engine results reproduced and sorted according to the nearest neighbors.
- Let's zoom in for a simple example…

Instrument Name Abbreviated	Instrument Type	Total Mass (kg)	Total Max Power (W)
APS-Glory	Optical	24.72	7.04
CERES	Optical	34.71	28.70
CERES-SuomiNPP	Optical	48.33	28.72
CIRS	Optical	7.52	22.12
CRISM	Optical	25.76	35.72
CRISP	Optical	26.02	31.74
FUV	Optical	7.22	20.29
FUV_ICON	Optical	28.63	9.02
HRI_Deep_Impact	Optical	5.01	49.80
IRAC	Optical	16.06	6.92
IRS	Optical	5.19	51.25
ISS	Optical	26.92	54.78
LRI			
MDI			
MIGHTI			
MIPS			
MOLA MGS			
NOMAD			
PFS			
PMIRR	Optical	28.60	33.42
SOFIE	Optical	16.61	22.16
TIDI	Optical	11.74	18.97
TIM_Glory	Optical	23.43	23.52
TOMS	Optical	26.88	56.29
TRACE	Optical	50.92	53.40
VIMS	Optical	6.33	5.44
VIRS	Optical	9.62	6.74

Random Numbers, not actual data.

SUMMARY DATA	Instrument Type	Total Mass (kg)	Total Max Power (W)
Average:		20.11	27.79
Minimum:		1.04	4.75
Maximum:		50.92	59.67

kNN Estimate Inputs:	Instrument Type	Total Mass (kg)	Total Max Power (W)
		50	

Instrument Name Abbreviated	Instrument Type	Total Mass (kg)	Total Max Power (W)
TRACE	Optical	50.92	53.40
CERES-SuomiNPP	Optical	48.33	28.72
LRI	Optical	40.01	9.41
CERES	Optical	34.71	28.70
PFS	Optical	32.48	34.52
FUV_ICON	Optical	28.63	9.02
PMIRR	Optical	28.60	33.42
ISS	Optical	26.92	54.78
TOMS	Optical	26.88	56.29
CRISP			
CRISM			
APS-Glory			
TIM_Glory			
SOFIE			
IRAC			
MIGHTI			
MDI	Optical	13.07	5.58
TIDI	Optical	11.74	18.97
VIRS	Optical	9.62	6.74
CIRS	Optical	7.52	22.12
FUV	Optical	7.22	20.29
NOMAD	Optical	6.39	38.26
VIMS	Optical	6.33	5.44
IRS	Optical	5.19	51.25
HRI_Deep_Impact	Optical	5.01	49.80
MIPS	Optical	4.10	32.13
MOLA MGS	Optical	1.04	4.75

Random Numbers, not actual data.

Knn Weighted Averages:	Instrument Type	Total Mass (kg)	Total Max Power (W)
			35.39

Search Engine: Weighted Averages Using kNN

- Simple example: Let's input 50 kg as our kNN input.
- The code will sort the Search Engine results according to the nearest neighbors (in this case, those closest to 50 kg),
- Below that, the code creates a k nearest neighbor weighted average for Max Power.

kNN Estimate Inputs:	Instrument Type	Total Mass (kg)	Total Max Power (W)
		50	

Instrument Name Abbreviated	Instrument Type	Total Mass (kg)	Total Max Power (W)
TRACE	Optical	50.92	53.40
CERES-SuomiNPP	Optical	48.33	28.72
LRI	Optical	40.01	9.41
CERES	Optical	34.71	28.70
PFS	Optical	32.48	34.52
FUV_ICON	Optical	28.63	9.02
PMIRR	Optical	28.60	33.42
ISS	Optical	26.92	54.78
TOMS	Optical	26.88	56.29
CRISP	Optical	26.02	31.74
CRISM	Optical	25.76	35.72
APS-Glory	Optical		04
TIM_Glory	Optical		52
SOFIE	Optical		16
IRAC	Optical		92
MIGHTI	Optical	15.73	59.67
MDI	Optical	13.07	5.58
TIDI	Optical	11.74	18.97
VIRS	Optical	9.62	6.74
CIRS	Optical	7.52	22.12
FUV	Optical	7.22	20.29
NOMAD	Optical	6.39	38.26
VIMS	Optical	6.33	5.44
IRS	Optical	5.19	51.25
HRI_Deep_Impact	Optical	5.01	49.80
MIPS	Optical	4.10	32.13
MOLA MGS	Optical	1.04	4.75

Random Numbers, not actual data.

Knn Weighted Averages:			
			35.39

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And More!

NICM 10: And more!

- Non-CER instruments will be added to the database.
- A new Mission View summary tab will be included.
- The Search Engine results table will be unlocked for easy sorting etc.
- The user's minimum and maximum now appear along with the user's most likely inputs in the Subsystem Tool's box and whisker plot.
- Search engine will include "not equal to" search capability.
- Multiple build override capability.
- Last, but certainly not least, all models will be refreshed with the recently added instrument data.

NICM Publications & Presentations

1. IEEE Aerospace

- "Salvaging Data Records with Missing Data: Data Imputation using the Multivariate t Distribution," 2021 Aerospace Conference, Virtual, March 2021, M. Hooke, J. Mrozinski, M. DiNicola
- "NASA Instrument Cost Model for Explorer-like Mission Instruments," 2014 Aerospace Conference, Big Sky, MT, March 2014, H. Habib-Agahi, J. Mrozinski, G. Fox.
- "NASA Instrument Cost and Schedule Model," 2011 Aerospace Conference, Big Sky, MT, March 2011, H. Habib-Agahi, G. Fox, J. Mrozinski.

2. AIAA Space

- "NASA Space Flight Instruments: Cost Time Trends," 2016 Space Conference, Long Beach, CA, September 2016, J. Mrozinski, M. DiNicola, H. Habib-Agahi.
- "Latest NASA Instrument Cost Model (NICM): Version VI," 2014 Space Conference, San Diego, CA, August 2014, J. Mrozinski, H. Habib-Agahi, G. Fox, G. Balls.
- "NICM Schedule & Cost Rules of Thumb," 2009 Aerospace Conference, Pasadena, CA, September, 2009, H. Habib-Agahi, G. Fox, G. Ball.

3. International Cost Estimation and Analysis Association (ICEAA)

- "NASA Instrument Cost Model (NICM)," 2014 International Cost Estimation and Analysis Association (ICEAA) Professional Development & Training Workshop, Denver, CO, June 2014, H. Habib-Agahi, J. Mrozinski, G. Fox.

NICM Publications & Presentations

NASA Cost and Schedule Symposium Presentations

- 2021: “NASA Instrument Cost Model: Mission Class’s Impact, Imputation, Multiple Builds and More: New Features in the Latest Version of NICM,” Virtual Presentation.
- 2020: NICM 9 announced 2020 NASA Cost & Schedule Virtual Gathering.
- 2019: “NICM 8.5,” Johnson Space Center, J. Mrozinski, M. Ramirez.
- 2018: “NASA Instrument Cost model: Version VIII Major Improvements,” Goddard Space Flight Center, J. Mrozinski, J. Johnson.
- 2017: “NICM – Cryocooler,” NASA Headquarters, J. Mrozinski, M. DiNicola.
- 2017: “The Silent “S” in NICM – NICM Schedule Capabilities”, NASA Headquarters, J. Mrozinski, M. DiNicola.
- 2016: “NASA Instrument Cost Model Impact of Mission Class on Cost,” Glenn Research Center, August 2016, J. Mrozinski, M. DiNicola, H. Habib-Agahi.
- 2015: “NICM Version VII,” Ames Research Center, H. Habib-Agahi, J. Mrozinski, M. DiNicola.
- 2014: “Telescope Cost Estimating,” Langley Research Center, H. Habib-Agahi, J. Mrozinski.
- 2013: “NASA Instrument Cost Model for Explorer-like Mission Instruments,” Jet Propulsion Laboratory, H. Habib-Agahi, J. Mrozinski, G. Fox, G. Ball.
- 2012: “NASA Instrument Cost Model,” Applied Physics Laboratory, H. Habib-Agahi, J. Mrozinski.
- 2011: “NICM,” Johnson Space Center, J. Mrozinski.

Questions?

For Training or questions: NICM@jpl.nasa.gov

For Download:

- **Have a NASA login? Go to: oncedata.com**
- **All others: software.nasa.gov**

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April 26-28, 2022

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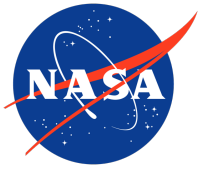

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