NASA Instrument Cost Model

NICM Version VII

Hamid Habib-Agahi
Joe Mrozinski
Mike DiNicola

NASA Cost Symposium, August 2015

Jet Propulsion Laboratory
California Institute of Technology

Copyright 2013 California Institute of Technology. Government sponsorship acknowledged.

NICM VII – What's New?

- Every Remote Sensing CER has been improved
  - Old data out!
  - New data in!
  - Fewer inputs required!
  - New CER splits!

- New Telescope CER added to the Tool

- New multi-variable input flagging system in place to warn of questionable input combinations.

Every Remote Sensing CER has been Improved

- Old data out!
  - Data from 1985 to 1990 has been removed from these CERs
  - Note: This data is still present in the NICM Search Engine if needed for analogies

- New data in!
  - NICM VI had 174 instrument of which 10 (1985-1990) data points were removed.
  - 30 instrument added for a total of 194 instruments used for the NICM VII CER.

Every Remote Sensing CER has been Improved

- Fewer inputs required!
  - Planetary Optical instruments no longer require Design Life
  - Fields instruments no longer require Design Life
  - Software no longer requires “Intensive Development” Boolean
  - Data rate is no longer used anywhere as an input
  - TRL is no longer used anywhere as an input
- New CER splits!
  - Microwave Instrument System Level CER has been split into 2 CERs: Active Microwave and Passive Microwave
  - Instrument Antenna Subsystem level CER has been split into 2 CERs: Active Microwave Antenna and Passive/Other Antennas

Planetary Optical System CER

NICM VII	NICM VI
Total Instrument B/C/D Cost = 1,208 * TotalMass^0.43 * TotalMaxPwr^0.50 R2 = 78%, PE = 39%, N = 38	Sensor Cost = 277 * TotalMass^0.43 * TotalMaxPwr^0.41 * DesignLife^0.38 R2 = 76%, PE = 46%, N = 32

Earth Orbiting Optical System CER

NICM VII	NICM VI
Total Instrument B/C/D Cost = 673 * TotalMass^0.48 * TotalMaxPwr^0.51 R2 = 71%, PE = 54%, N = 24	Sensor Cost = 979.9 * TotalMass^0.33 * TotalMaxPwr^0.36 * DataRate^0.09 R2 = 89%, PE = 59%, N = 13

Microwave Instruments System CER

<table>
<tr><th>NICM VII</th><th>NICM VI</th></tr>
<tr><td>Active Microwave Instruments
Total Instrument B/C/D Cost = 1,244 * TotalMass^0.36 * TotalMaxPwr^0.50

R2 = 77%, PE = 52%, N = 10</td><td rowspan="2">Active & Passive Microwave Instruments

Sensor Cost = 19,899 * TotalMass^0.28 * TotalMaxPwr^0.33 * DataRate^0.090 * TRL^-1.3

R2 = 88%, PE = 48%, N = 13</td></tr>
<tr><td>Passive Microwave Instruments
Total Instrument B/C/D Cost = 1,664 * TotalMass^0.38 * TotalMaxPwr^0.40

R2 = 83%, PE = 42%, N = 12</td></tr>
</table>

Fields System CER

NICM VII	NICM VI
Total Instrument B/C/D Cost = 1,646 * TotalMass^0.31 * TotalMaxPwr^0.35 R2 = 79%, PE = 40%, N = 11	Total Instrument B/C/D Cost = 952.1 * TotalMass^0.18 * TotalMaxPwr^0.24 * DsgnLife^0.27 R2 = 87%, PE = 43%, N = 10

Particles System CER

NICM VII	NICM VI
Total Instrument B/C/D Cost = 233 * TotalMass^0.35 * TotalMaxPwr^0.45 * DesignLife^0.49 R2 = 66%, PE = 49%, N = 42	Total Instrument B/C/D Cost = 825.2 * TotalMass^0.33 * TotalMaxPwr^0.53 * DesignLife^0.17 R2 = 65%, PE = 33%, N = 20

NICM-E CER

NICM VII	NICM VI
Total Instrument B/C/D Cost = 740 * TotalMass^0.42 * TotalMaxPwr^0.31 R2 = 91%, PE = 30%, N = 18	Total Instrument B/C/D Cost = 661 * TotalMass^0.43 * TotalMaxPwr^0.34 R2 = 93%, PE = 30%, N = 20

Wraps CERs

NICM VII	NICM VI
Management Cost = 5% * **Total Instrument** Cost^1.03 R2 = 84%, PE = 55%, N = 133	Management Cost = 0.07124 * **Sensor** Cost^1.03 R2 = 85%
Systems Engineering Cost = 15% * **Total Instrument** Cost^0.94 R2 = 82%, PE = 54%, N = 132	Systems Engineering Cost = 0.4931 * **Sensor** Cost^0.86 R2 = 75%
Product Assurance Cost = 2% * **Total Instrument** Cost^1.06 R2 = 82%, PE = 61%, N = 127	Product Assurance Cost = 0.1427 * **Sensor** Cost^0.94 R2 = 91%
Integration & Test Cost = 2% * **Total Instrument** Cost^1.15 R2 = 86%, PE = 58%, N = 130	Integration & Test Cost = 0.1457 * **Sensor** Cost^1.00 R2 = 87%

Antenna Subsystem CER

<table>
<tr><th>NICM VII</th><th>NICM VI</th></tr>
<tr><td>Active Microwave Antenna Subsystem
Cost = 23 * AntMass^0.41 * TotalMaxPwr^0.94

R2 = 89%, PE = 71%, N = 10</td><td rowspan="2">Antenna Subsystem
Cost = 758 * AntMass^0.92

R2 = 87%, PE = 57%, N = 14</td></tr>
<tr><td>Passive Microwave/Other Antenna Subsystem
Cost = 914 * AntMass^0.70

R2 = 83%, PE = 44%, N = 15</td></tr>
</table>

Optics Subsystem CER

NICM VII	NICM VI
Cost = 1,509 * OpticsMass^0.54 R2 = 72%, PE = 63%, N = 48	Cost = 1,424 * OpticsMass^0.56 R2 = 72%, PE = 60%, N = 42

Electronics Subsystem, Earth Orbiting CER

NICM VII	NICM VI
Cost = 457 * ElecMass^0.43 * TotalMaxPwr^0.46 R2 = 83%, PE = 54%, N = 34	Cost = 771 * ElecMass^0.40 * TotalMaxPwr^0.40 R2 = 77%, PE = 71%, N = 27

Electronics Subsystem, Planetary CER

NICM VII	NICM VI
Cost = 1,518 * ElecMass^0.71 R2 = 66%, PE = 55%, N = 64	Cost = 2,047 * ElecMass^0.57 R2 = 71%, PE = 40%, N = 47

Structures/Mechanisms Subsystem CER

NICM VII	NICM VI
Cost = 232 * TotalMass^0.73 R2 = 63%, PE = 84%, N = 91	Cost = 340 * TotalMass^0.69 R2 = 73%, PE = 62%, N = 59

Detectors Subsystem CER

Photovoltaic/Photodiode/Photo Multiplier Tube (PMT) Detectors
& Fields/Ion Detectors

NICM VII	NICM VI
Fields/Ion Detectors Cost = 916 * DetectMass^0.45 *PPP Detectors* Cost = 2,783 * DetectMass^0.45 R2 = 65%, PE = 76%, N = 34	*Fields/Ion Detectors* Cost = 1,002 * DetectMass^0.33 *PPP Detectors* Cost = 3,498 * DetectMass^0.33 R2 = 57%, PE = 72%, N = 36

Detectors Subsystem CER

CCD Detectors

NICM VII	NICM VI
Cost = 1,579 * DetectMass^0.67 R2 = 83%, PE = 83%, N = 16	Cost = 1,659 * DetectMass^0.87 R2 = 84%, PE = 86%, N = 12

Thermal* Subsystem CER

NICM VII	NICM VI
Cost = 569 * ThermMass^0.55 R2 = 70%, PE = 71%, N = 49	Cost = 562 * ThermMass^0.52 R2 = 61%, PE = 73%, N = 49

*not including the cryocooler/cryostat/dewar delta

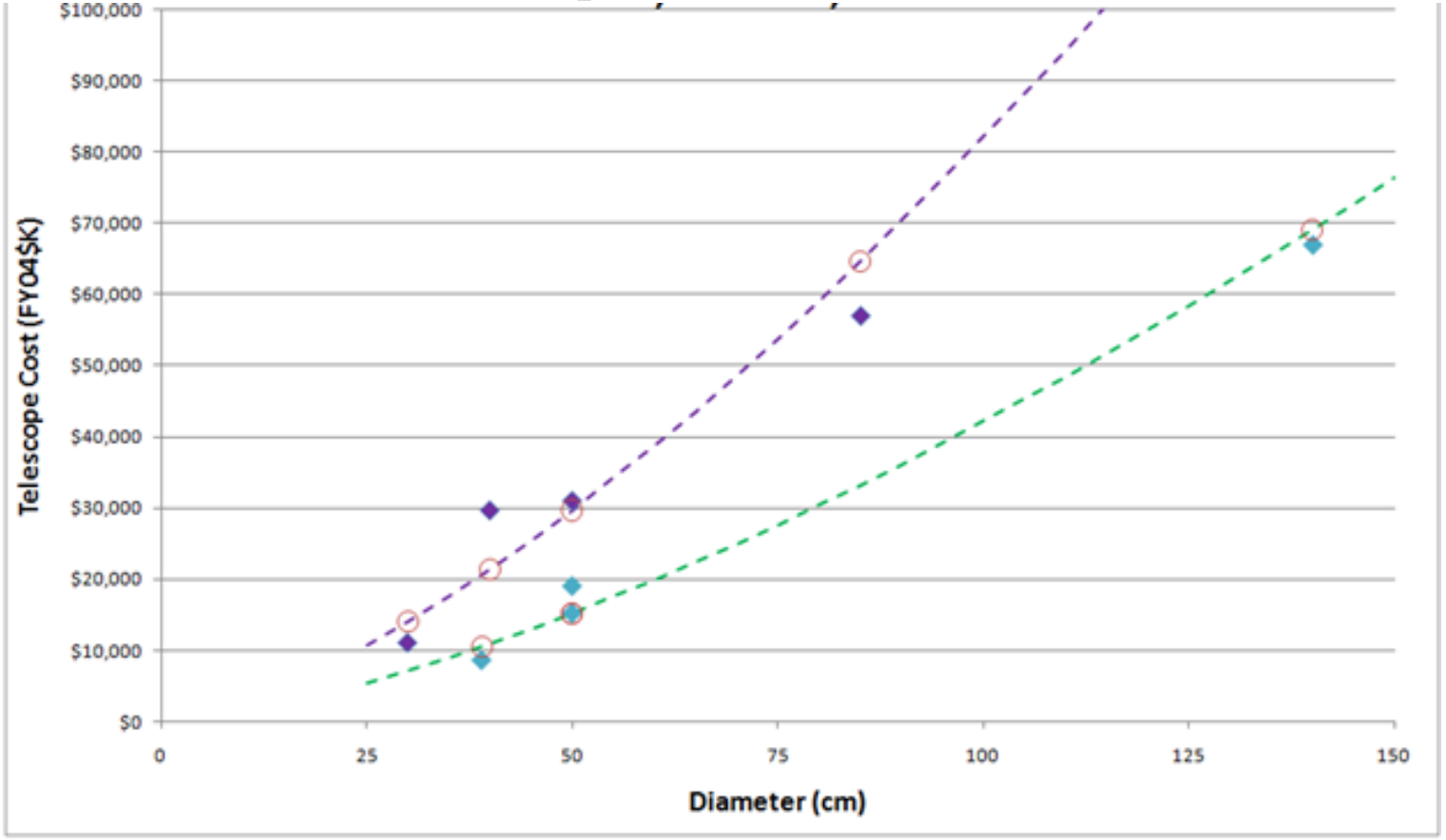
Software Subsystem CER

NICM VII	NICM VI
Cost = 13% * HW Cost^0.91 R2 = 73%, PE = 65%, N = 58	Cost = 4.3% * HW Cost *if Low Level of SW Development Intensity* Cost = 12.3% * HW Cost *if High Level of SW Development Intensity* R2 = 92%, N = 48

HW Cost = Sum of all instrument hardware costs

Telescope CER

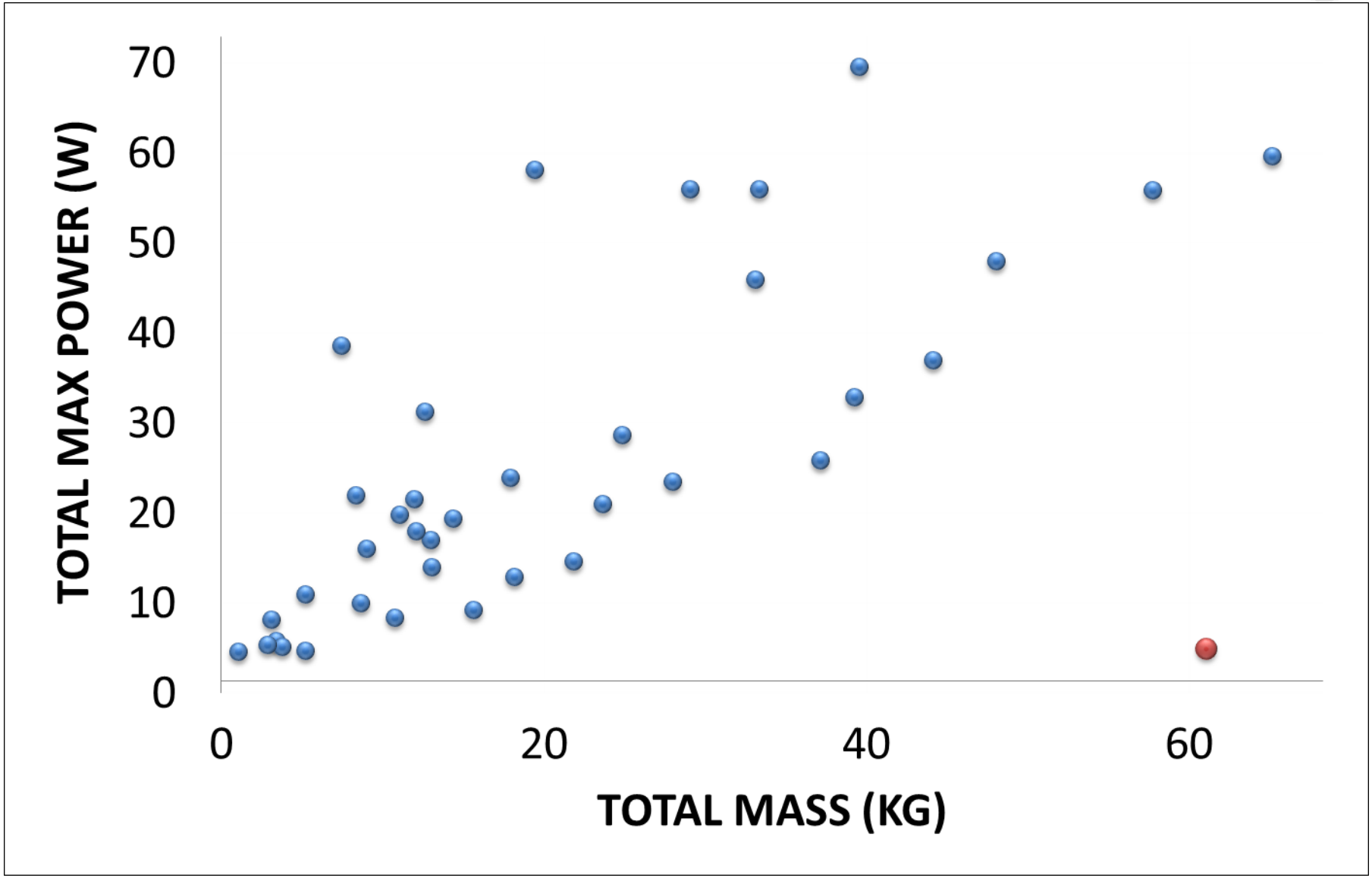
- Cost = {49 for Visible/UV or 95.4 for Infrared}*(Diameter[cm])$^{1.47}$
- R^2 = 93%, SE = 23%, PE = 37%
- Green: Vis/UV. Purple: IR



Multi-Variable Input Flagging

- NICM's old flag system checked inputs independently.
  - Example for an Optical Planetary instrument:
    - Mass = 61 kg
    - Power = 5 W
    - These two parameters pass their individual flags, i.e., both are in range
- The new Multi-Variable Input Flagging system allows the user to visualize combinations of variables along with previously flown instrument data to flag poor combinations.
  - Plotting the example above yields:

Multi-Variable Input Flagging



Thank you!

- Questions?