NASA Instrument Cost Model for Explorer-like Mission Instruments

NICM-E

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Motivation

- The NICM team received feedback that NICM was predicting costs much higher than grass roots estimates for many Explorer class mission instrument proposals
- Previous Explorer class instruments were found to have lower actual costs compared to the other instrument costs in the NICM database.
- Why is this? A class of instruments was identified that contrasts with the rest of the NICM instruments in the following way:
  - Flew on Class C missions AND
  - University or research foundations led and performed the majority of the instrument development (design through delivery) AND
  - Significant inheritance
- The NICM Team set out to create a new CER which would be applicable to this class of Explorer-like mission instruments.

Objective

A. To create a new Cost Estimating Relationship (CER) for instruments with the following characteristics:
   1. Flew on C Class Missions AND
   2. University or research foundations led and performed the majority of the instrument development (i.e. design through delivery) AND
   3. Significant inheritance

B. To determine if this new CER is indeed needed in addition to the traditional NICM CERs.

Methodology

- Collect and normalize Explorer class mission instrument data
- Identify key cost drivers for this data using principal components analysis
- Develop a Cost Estimating Relationship (CER) using the identified cost drivers
- Validate the CER using bootstrap cross validation
- Compare the utility of this new CER to the traditional NICM CERs
- Create recommendations for the new CER use

Data Collection and Evaluation

- Data Collection and Common Characteristics
  - Collected instrument technical and programmatic data for 20 instruments on missions led by Goddard, JPL and APL.
    - Note that 2 of these instruments did not fly on Explorer class missions, but did have the 3 main characteristics and thus were included
    - Note that 8 instruments are Optical, 4 are Fields, 8 are Particles and there are no Microwaves.
- Data Evaluation
  - Converted to same fiscal year as traditional NICM data, $FY2004
  - Normalized cost data where appropriate
  - Verified risk class
  - Determined design inheritance (i.e. previously flown instruments, subsystems/components, etc.).
  - Determined university and research foundation involvement.

NICM-E Instrument Data

Instrument Name	Lead Center	Instrument Type	Sensor Cost ($K FY04)	B/C/D Cost ($K FY04)	Mass (kg)	Maximum Power (W)
CHIPS	GSFC	Optical	$4,521	$5,014	23.67	30.00
CIPS	GSFC	Optical	$7,010	$10,483	24.00	39.00
EFI_THEMIS	GSFC	Fields	$2,308	$2,904	16.01	13.73
EFPE	GSFC	Fields	$5,730	$7,161	28.45	15.90
ESA_FAST	GSFC	Particles	$4,880	$6,100	23.97	13.10
ESA_THEMIS	GSFC	Particles	$1,176	$1,480	3.85	1.77
GALEX	JPL	Optical	$18,609	$23,662	135.10	191.00
GUVI	APL	Particles	$6,105	$8,355	19.07	26.69
IRIS	GSFC	Optical	$20,746	$28,917	97.30	96.30
LEICA	GSFC	Particles	$2,424	$3,030	9.76	9.32
MAG-FAST	GSFC	Fields	$1,680	$2,100	7.03	2.10
MAST/PET	GSFC	Particles	$2,776	$3,470	11.27	8.01
NuStar	JPL	Optical	$36,870	$42,275	179.00	200.00
RHESSI	GSFC	Optical	$21,904	$30,669	127.00	175.20
SOFIE	GSFC	Optical	$6,346	$9,996	38.00	52.00
SST	GSFC	Fields	$1,244	$1,566	1.74	1.38
TEAMS	GSFC	Particles	$2,480	$3,100	10.31	4.50
TIDI	APL	Particles	$12,700	$16,081	40.57	53.00
TRACE	GSFC	Optical	$19,116	$23,895	59.13	69.00
ULEIS	APL	Particles	$6,260	$7,512	18.40	21.20

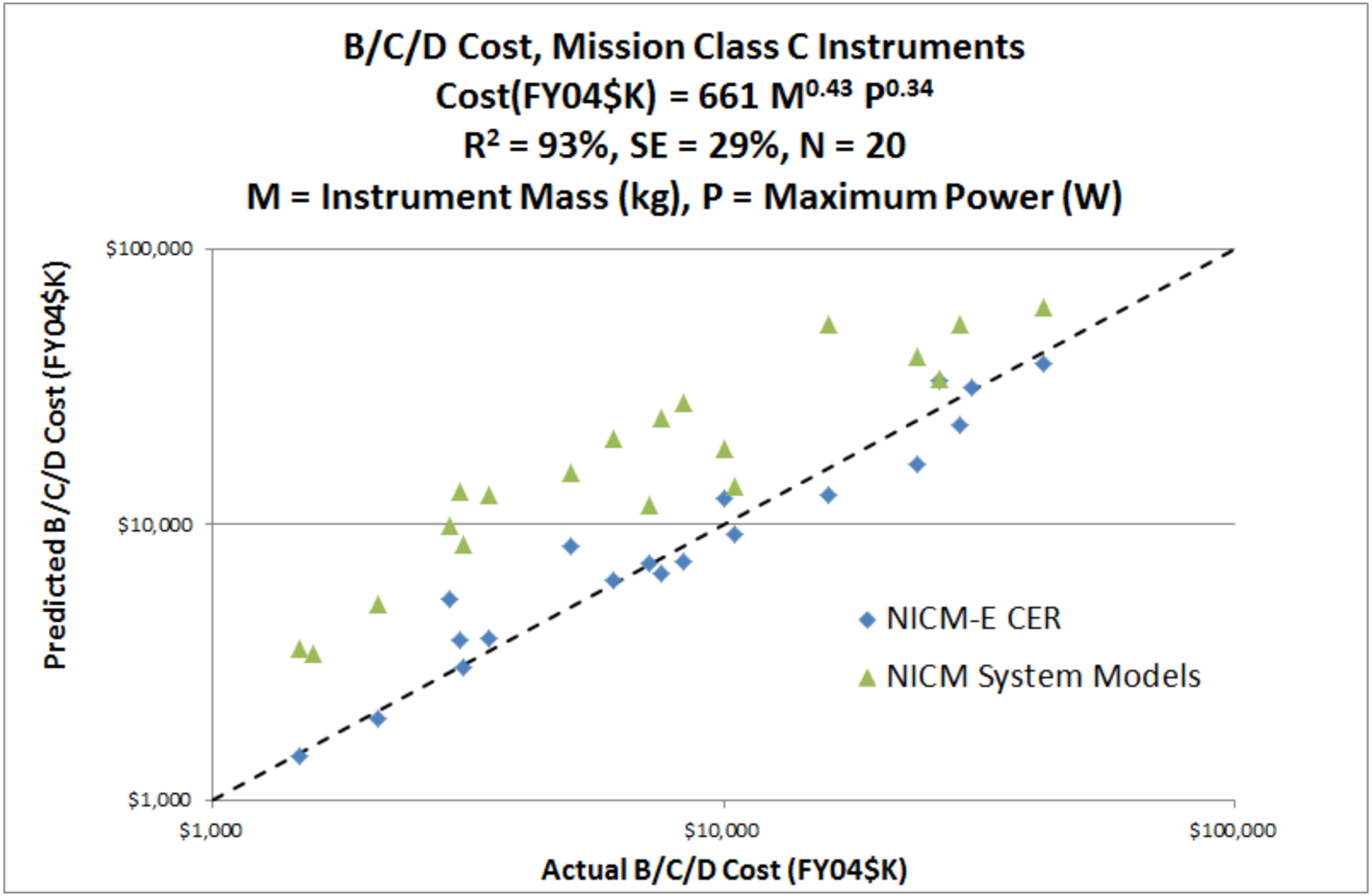
New CER and Validation Results

- Principal Component Analysis determined instrument mass and maximum power to be the two main sensor cost drivers:

$$\textbf{Cost (\$K FY04)} = 661\ M^{0.43}\ P^{0.34}$$

  - High coefficient of multiple correlation of 93% with a standard error of 29%
  - Prediction Error from Bootstrap Cross Validation with 10,000 ssamples is 30.4%, i.e. to obtain 70% confidence the CER cost (i.e. median cost) is only increased 16%.

NICM-E vs. Traditional NICM



Analysis and Results

- As the statistical analysis indicates, the new CER explains 93% of the cost variation in Explorer-like mission instruments with the 3 required characteristics: Flew on a Class C mission, University led development, and significant inheritance.
- There was no discernible cost model difference between instrument types: Optical, Fields or Particles.
- As displayed on the figure, points on the dashed line have actual cost equal to the NICM-E CER cost estimate.
- Furthermore, when using the traditional NICM System Level CERs, all 20 instruments are predicted to have much higher costs than their actual costs.
- The analysis therefore indicates a need for this new CER for Explorer-like mission instruments.

Recommendations

- Use NICM-E to estimate cost for instruments that:
  - Will fly on a Class C mission AND
  - Where university or research foundations will lead and perform the majority of the instrument development (i.e. design through delivery) AND
  - Have significant inheritance
- If the instrument does not meet any of the above three criteria, use the traditional NICM System CERs.
- For instruments that meet some of the criteria but not all, run both NICM-E and the traditional NICM and interpolate.