OFFICE OF THE DIRECTOR OF NATIONAL INTELLIGENCE

(U) ACQUISITION STRATEGY STUDY

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LEADING INTELLIGENCE INTEGRATION

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Audience: NASA Cost Symposium

Agenda

- **Study Background**
- **Problem Statement**
- **Dataset**
- **Methodology**
- **Summary**
- **Future Work**
- **Backup**

ODNI Acquisition Strategy Study

- **ODNI/SRA/CA initiated a study of the effect of acquisition strategy, specifically contract type, on the ultimate cost and schedule of a satellite program. The study includes three parts:**
  1. Review of existing literature and studies (IDA)
  2. *Data-driven analysis (Aerospace)*
  3. Interviews and discussion with agencies and industry contractors (JSCC)
- **Purpose**
  1. Understand the impacts of ongoing National Security Space (NSS) acquisition strategies and determine how to incorporate any adjustments needed in our cost estimates, models, and affordability analyses
     - Investigate existing historical literature and studies in this field
     - Create an extensive cross-agency database of civil, commercial, and NSS satellites; focus on data which may play a significant role in determining best strategies for acquiring or estimating space systems
     - Complete a data-driven analysis of the realities of satellite program technical and programmatic characteristics, as related to contract type
  2. Brief results to inform other organizations acquiring satellite systems

Perceived Benefits of Fixed-Price Contracts

- **We know from the literature review conducted by IDA[1] that:**
  - Prevailing wisdom, as documented in the literature reviewed, suggests several perceived benefits of a fixed-price contract type:
    - Incentivize contractors to reduce costs
    - Reduce cost growth by suppressing the government's appetite for increasing requirements
    - Increase the probability of mission success by suppressing government's appetite for changes
  - A fixed-price approach should be used when acquisitions meet certain criteria
    - Uses technologies and subsystems that are available today
    - Performance and implementation of the satellite system can be specified in the contract
    - No external dependencies that will affect the design, cost, or schedule

- **However, in this imperfect world, fixed-price approaches may be undertaken**
  - When the above criteria are not met
  - When the above criteria are met at program start, but the acquisition environment changes
  - Not making a judgment in this study on whether the contract strategy was optimized for a given program

- **ODNI has assembled a database of satellite program data to test these perceptions**

Dataset (1/3)

- **Leverage existing studies and databases as much as possible**
- **Documented sources include studies, datasets, and databases maintained by multiple civil, military, and NSS cost analysis groups**
- **Collected additional data from:**
  - Program CPRs
  - Internet searches
  - Individuals: former and current program managers, systems engineers, Aerospace program office personnel
- **Validated across multiple sources where possible**
- **Normalized as needed**

Dataset (2/3)

- **Primary data fields used in the study include:**
  - Organization: Commercial, NASA, NSS
  - Contract Type: CPFF/NF, CPIF/AF, FPIF/AF, FFP
  - Contract Block Status: New Contract, Follow-on-Within-Block, Exercised Option
  - Design Heritage: Development, Major Modification, Production
  - Mission Type: Imaging, Communications/Navigation/Signals, Scientific/Experimental
  - Final Dry Weight (lbs)
  - Design Life (months)
  - Normalized Schedule Development Duration (months): eliminates periods of storage, work stoppage, or launch delay from total schedule
  - Schedule Growth: from initial estimated launch date (prior to or at PDR) to final launch date
  - NR + T1 Cost (FY12 M$): flight system cost only, no ground, ops, launch, system of systems
    - **Cost not Price**: contractor actual cost on fixed-price contracts, no prime fee included
  - Cost Growth: from program estimate at contract award to final NR + T1 cost
  - k$/lb: the total NR + T1 cost divided by final dry weight
  - CoBRA Complexity Value
  - Bus/Instrument New Design Factors: scale from 0.3 to 1.6

Dataset (3/3)

- **Total of 259 earth-orbiting satellite programs**
- **Study focus is on programs which are completed, first of block**
  - Reduces total dataset to 167 programs
- **Only include those completed programs where could identify a prime contract type as CP or FP**
  - Excludes programs that were in-house or student-built
  - Reduces total dataset to **114 satellite programs: 48 procured on cost-plus contracts and 66 on fixed-price contracts**
    - Launch dates range from 1970 to 2011; cost data includes 8 programs launched prior to 1990 and 106 launched after 1990

Data Completion	Mission Type	Final Dry Weight	CoBRA Complexity	Design Life	NR + T1 Cost	Cost Growth	Development Schedule	Schedule Growth	Bus New Design	Ins New Design
% Fields Populated	99%	99%	42%	98%	72%	19%	99%	20%	30%	30%

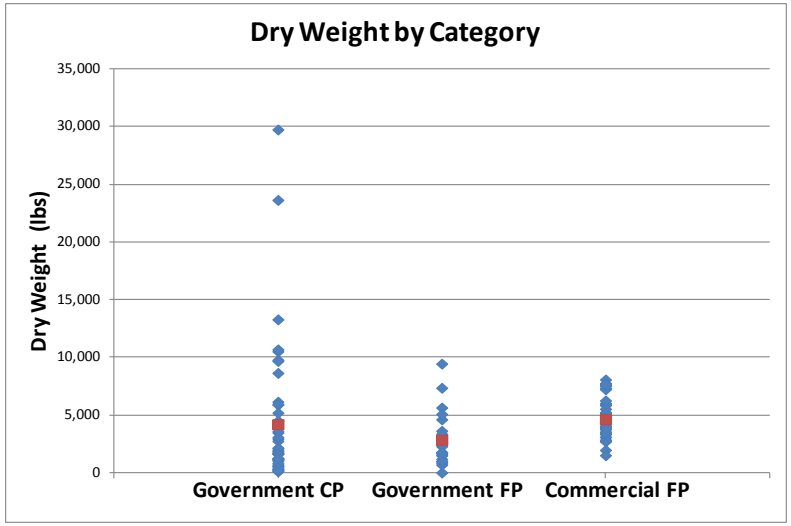
Table 1: Displays the percentage of satellite programs in the database for which a given data field is populated.

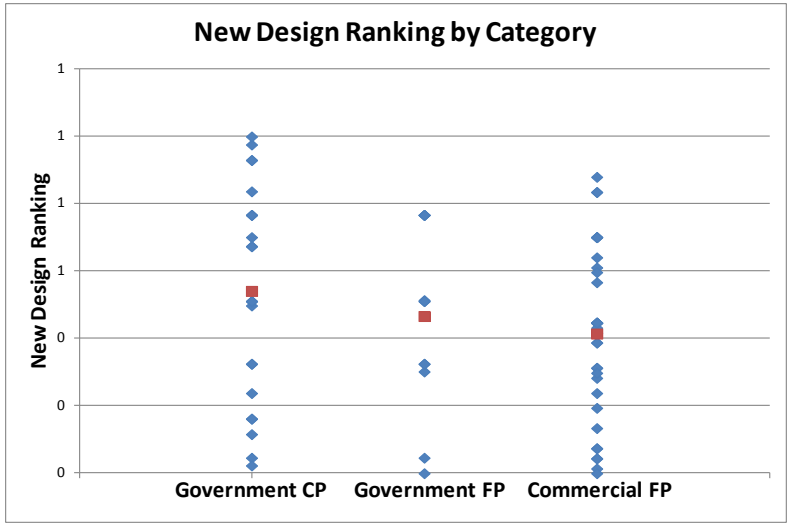
Hypothesis Testing: Methodology

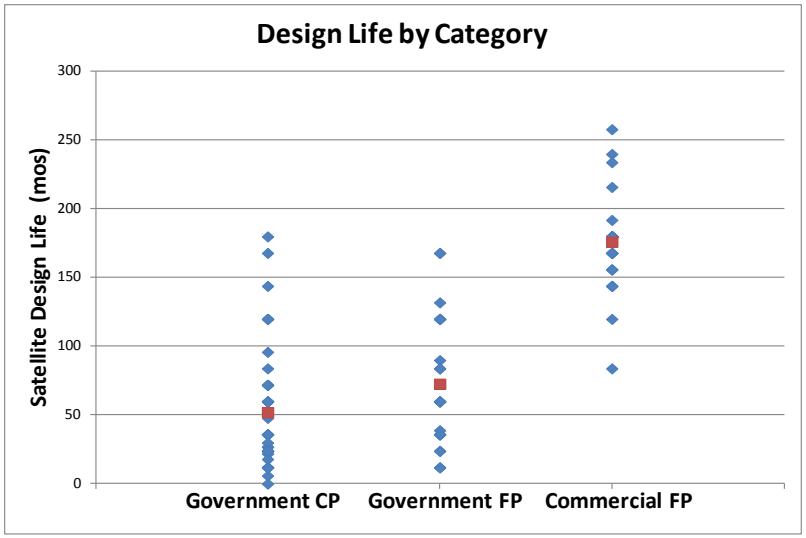
- **(U) We will use statistical hypothesis testing to detect significant differences in technical and programmatic parameters when satellite programs are separated by contract type**
  - (U) t-test will test for differences in means, F-test for differences in variance
  - (U) Test will yield a p-value; use 90% significance criteria
    - (U) If p-value < 0.1, then we consider the difference to be significant for the purposes of this study (green cell)
  - (U) Start by testing each data field *independently*

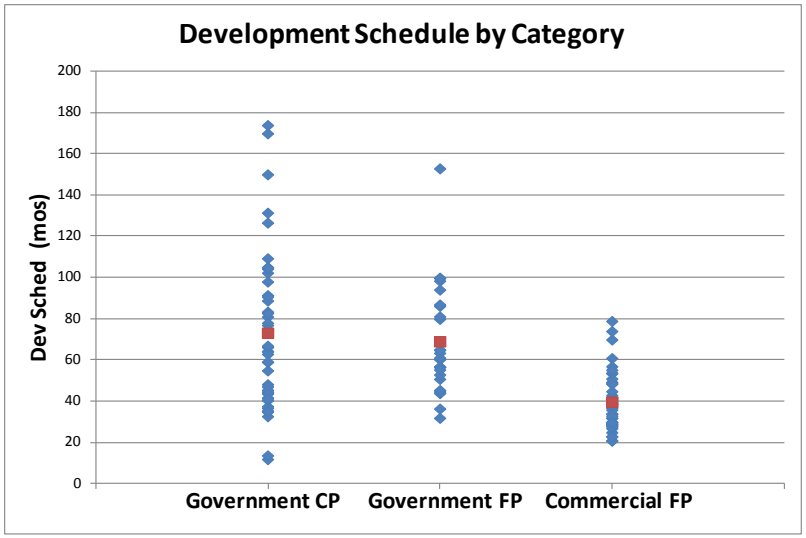
- **(U) Divide satellites into three categories: Government CP, Government FP, and Commercial FP**

Graphic Comparisons: By Category









Hypothesis Testing: By Category

- **We do not see a significant difference between Government CP and FP for**
  - Dry Weight
  - New Design
  - NR + T1 Cost
  - Schedule

Gov CP vs. Gov FP

Parameter	n		Average		Standard Deviation	
	Gov CP	Gov FP	Gov CP	Gov FP	Gov CP	Gov FP
Dry Weight	45	25	4,245	2,893	**5,957**	**2,188**
New Design Rank	23	12	54%	47%	31%	27%
Design Life	44	25	**52.0**	**72.8**	43.6	46.0
NR + T1 Cost	24	16	$743	$452	**$842**	**$235**
k$/lb	24	16	**$248**	**$166**	**$156**	**$77**
Schedule Duration	45	25	73.3	69.1	**37.5**	**26.6**

- **We do not see a significant difference between Government FP and Commercial FP for**
  - New Design

Gov FP vs. Comm FP

Parameter	n		Average		Standard Deviation	
	Gov FP	Comm FP	Gov FP	Comm FP	Gov FP	Comm FP
Dry Weight	25	42	**2,893**	**4,681**	2,188	1,753
New Design Rank	12	34	47%	41%	27%	25%
Design Life	25	42	**72.8**	**176.3**	**46.0**	**28.2**
NR + T1 Cost	16	42	**$452**	**$217**	$235	$181
k$/lb	16	42	**$166**	**$51**	$77	$55
Schedule Duration	25	42	**69.1**	**39.9**	**26.6**	**14.2**

- **We do not see a significant difference between Government CP and Commercial FP for**
  - Dry Weight
  - New Design

Gov CP vs. Comm FP

Parameter	n		Average		Standard Deviation	
	Gov CP	Comm FP	Gov CP	Comm FP	Gov CP	Comm FP
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Schedule Duration	45	42	**73.3**	**39.9**	**37.5**	**14.2**

Hypothesis Testing: Summary

- **Dividing Government satellites into CP and FP categories and comparing to Commercial FP satellites, we find:**
  - Government CP satellites, on average, have a shorter design life, and higher cost per pound than Government FP satellites
  - Commercial FP satellites have, on average, a significantly higher weight and longer design life than Government FP satellites, while also having, on average, significantly lower cost, lower cost per pound, and shorter schedules.

- **Let's take a closer look**
  - First, examine our data: could anything in our dataset be biasing results?
  - Vast majority of Commercial FP satellites are communications satellites
  - Try taking mission type into account

Cluster Analysis: Methodology

- **Try to eliminate other possible underlying causes of the difference in cost, such as the variance in technical parameters commonly associated with cost**

- **Break data into technically-similar clusters of satellites according to commonly-used parameters such as mission type, dry weight, and design life**
  - MATLAB, a standard analysis software package used for k-means clustering

Cluster	Count	Mission Type	Count: (CP-FP)
1	7	Imaging	5-2
2	**32**	**Imaging**	**19-13**
3	14	Imaging	14-0
4	**39**	**Comm/Nav/Sig**	**19-20**
5	56	Comm/Nav/Sig	7-49
6	**30**	**Comm/Nav/Sig**	**21-9**
7	5	Sci/Exp	4-1
8	22	Sci/Exp	17-5

Cluster Analysis: Results

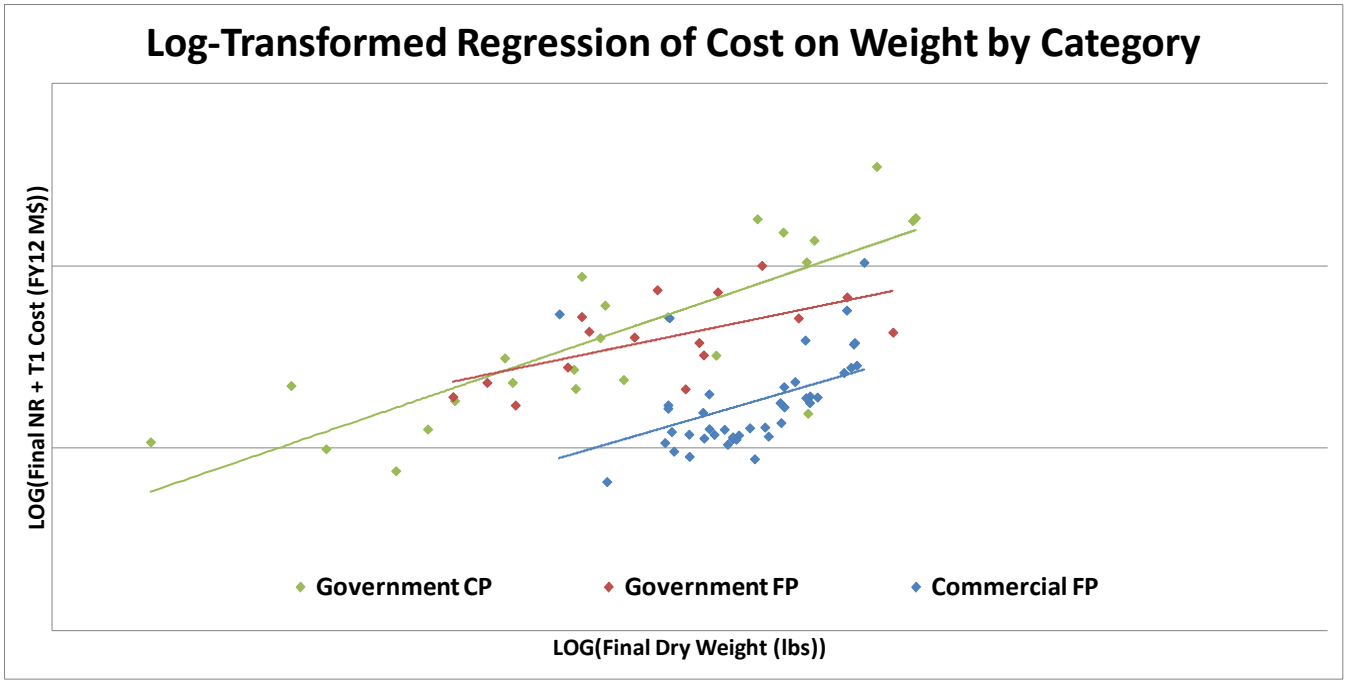
- **Within selected clusters where data is available, satellites procured on cost-plus contracts have:**
  - Higher mean cost, both in total dollars and k$/lb

Cluster	Count	Mission Type	Count: Cost (CP-FP)	Cost (FY12 M$)		k$/lb (FY12)	
				Cost-Plus	Fixed-Price	Cost-Plus	Fixed-Price
2	32	Imaging	12-6	$579	$293	$225	$174
4	39	Comm/Nav/Sig	14-19	$1,679	$351	$201	$51
6	30	Comm/Nav/Sig	17-5	$409	$312	$219	$193

- **When we perform t-tests, *only Cluster 4* has a statistically significant difference, according to our criteria of p-value < 0.1**

Future Work

- **Transformed linear, nonlinear, logistic regression using full database of NSS, NASA, and Commercial**
  - Do residuals exhibit a relationship to contract type?
  - Can we identify common traits among satellites procured on a particular contract type?
  - Can we identify outliers, or satellites for which a sub-optimal contract type was chosen?



Backup

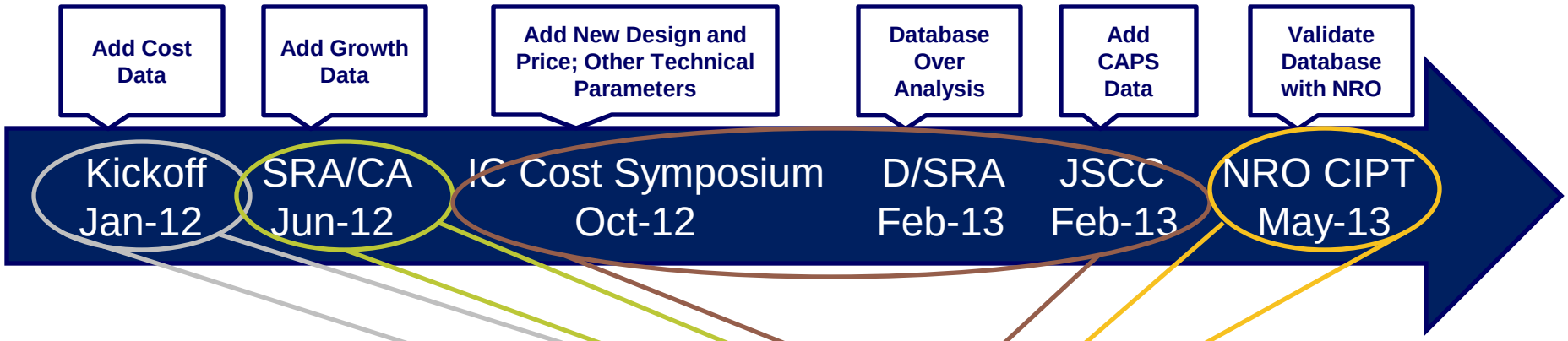
Complexity-Based Risk Assessment

- **CoBRA originated in the late 1990's with D. Bearden of The Aerospace Corporation**
  - Study goal was to assess NASA's "faster, better, cheaper" strategy with regard to a spacecraft's technical complexity
  - CoBRA II is now maintained by M. Kirtley, also of The Aerospace Corporation
- **The chief metric used in the study is a relative complexity value used to assess the overall complexity of a spacecraft and payload versus the cost and schedule**
  - The complexity value is calculated by collecting 40+ commonly-used satellite technical parameters such as dry weight, mission type, battery type, pointing control, etc. Complexity values for each parameter input are determined by normalizing that input against the range of database values to yield a percent value.
  - An overall complexity is then calculated by averaging the percent values and performing a normalization of that value against the range of satellite complexity values. This yields a complexity value between 0-100%

Cost Normalization

- **Used multiple Agency sources for NSS cost data**
  - Data is cost, no fee, and includes only flight system NR and T1 costs
  - Both sources break out NR, Rec, and T1
- **Used primarily NASA CADRe for NASA cost data**
  - Data was in a slightly different format from NSS data
  - Included lines such as project support, safety and mission assurance, systems engineering, government civilians, instruments, spacecraft bus, foreign contributions, and MPS pools
  - Did not include launch, ground system, operations or launch/operations planning, education/public outreach, algorithm development, or science team
  - Did include contractor actual cost for fixed-price missions; often CADRe will have notes regarding fixed-price contracts
  - Also, mission data for some NASA programs could also be found in USCM, which is based on contractor actual costs
- **Wherever the costs could not be broken out or weren't clear, or didn't validate across two or more sources, did not include the data point**

ODNI Acquisition Strategy Database



	Jan-12	Jun-12	Oct-12	May-13
Total # Satellites	214	214	229	345
Total First-in-Block	95	95	133	175
Cost-Plus	71	71	75	105
Fixed-Price	24	24	58	70
With Cost	0	63	63	121
With Schedule	126	126	130	169
# Data Fields	14	15	34	50+
Data Types	Schedule; Weight; Design Life; Contract Type	Cost; Complexity	Growth; Add'l Contract	New Design; Milestones; Phased Cost; Add'l Technical

Database has grown over time in both quantity and quality

Cluster Analysis Results: Schedule

- **Within selected clusters, satellites procured on cost-plus contracts do not show much difference in mean schedule duration and mean schedule growth from those procured on fixed-price contracts**
  - Not surprisingly, t-tests back up our observation that the differences are not statistically significant, according to our criteria of p-value < 0.1

Cluster	Count	Mission Type	Count: Schedule (CP-FP)	Schedule	
				Cost-Plus	Fixed-Price
2	32	Imaging	19-13	71.0	78.6
4	39	Comm/Nav/Sig	19-20	88.8	46.4
6	30	Comm/Nav/Sig	21-9	57.2	52.2

Data Fields and Definitions (1/3)

Data Field	Description
General and Technical Information	
Program Data Classification	Classification marker for the overall classification of the program's compiled data.
Data Collection Priority	The priority for collection; lower numbers are higher priority and the ranking is done by contractor
Program ID	A unique ID automatically assigned to each program in the database
Program Name	The program's commonly used name or acronym
Alias Program Name	Any prior or alternate program names, as well as spelled-out acronyms
Cluster	The technical cluster to which the program belongs (as presented in acquisition strategy brief at IC Cost Symposium)
Primary Mission Type	Normalized to four mission types: Imaging, Signals, Scientific/Experimental, and Communications/Navigation. Selected based on primary satellite mission. Weather and missile warning satellites have been categorized as Imaging. For analysis, Comm/Nav and Signals types are combined. Tech demos are considered Experimental.
# of Mission Types	Mission types as above; can be a number from 1 to 4 (in theory).
Mission Success	Normalized to Success, Failure, Partial Failure, Launch Vehicle Failure. Partial failure means minor to significant mission degradation, or mission had to be rescued/recovered through ad hoc efforts.
Design Heritage	Whether the satellite design was new development, major modification, or production. Minor modification is included with production. Major/Minor splits are a matter of judgment; a synopsis of the modifications should be included in the comments section.
Procuring Organization	The organization responsible for procurement of the satellite. Write all orgs, as needed (e.g. NASA/JAXA).
Normalized Organization	Normalized to three options: Commercial, NSS, and NASA. Where a satellite was a joint effort, used the organization handling the contract.
# Organizations	The number of different organizations involved in the acquisition of the satellite. This means ALL orgs (e.g. NASA/JAXA would be 2).
Final Dry Weight (lbs)	The dry weight of the satellite prior to launch, in pounds. Excludes all propellant. This is typically measured during pre-ship mass properties activity.
Weight Growth	The percentage growth in estimated final weight of satellite bus and payload between earliest documented point prior to or at PDR and final schedule at/after launch.
CoBRA Cost Complexity	This is the cost complexity value developed as part of the CoBRA study. It is a measure of satellite technical complexity as best defined to explain variations in program development cost. The value has been adjusted to account for general technological gains over time.
Design Life (months)	The amount of time a satellite is designed to stay in orbit and on mission; in months.
BOL Power	Theoretical (often modeled or calculated) peak solar array power production at the start of the satellite's life, in W. There is some question whether this definition is applied consistently across programs.
# of payloads	Number of distinct mission payloads or instruments. If instruments are an integrated system (e.g. filter on a telescope) and share the electronics units, then they count as one instrument. Place any judgment details in the comments section.
Orbital Regime	Normalized to: LEO, MEO, HEO, GEO, BEO (Beyond Earth Orbit - lagrange points, not interplanetary).
Requirements Volatility	Level of change in mission requirements over time (as defined in AFCAA schedule database). High, Medium, or Low.
% New Design	Total satellite % new design

Data Fields and Definitions (2/3)

Data Field	Description
General and Technical Data	
Bus New Design Factor	New Design Factor for spacecraft bus, 0.3-1.6: Simple Mod = 0.3 Extensive Mod = 0.7 New But Familiar = 1.0 Unfamiliar but Existing Technology = 1.2
Instrument New Design Factor	New Design Factor for spacecraft payload, 0.3-1.6: Simple Mod = 0.3 Extensive Mod = 0.7 New But Familiar = 1.0 Unfamiliar but Existing Technology = 1.2
C&DH Redundancy	The level of redundancy designed into the C&DH system. Can be single string, full, or partial redundancy.
GN&C Redundancy	The level of redundancy designed into the GN&C system. Can be single string, full, or partial redundancy.
Contract and Acquisition Data	
Contract Type	Long-form of the contract type including any interesting details in the comments
Normalized Contract Type	Normalized to two options: Cost-Plus and Fixed-Price. Cost-Plus included CPFF, CPIF, CPAF, and CPNF. Fixed-price includes FPIF, FPAF, and FFP.
Normalized Contract Sub-type	Normalized to four options: CPNF/FF, CPAF/IF, FPIF/AF, and FFP. Choose type of largest/costliest contract on program.
Separated Contract Sub-type	Separates out into: CNF, CPFF, CPIF, CPAF, FPIF, FPAF, FFP
Today's Corporation Name	Corporation name of prime contractor. Use name of company today, not at the time of satellite development.
Legacy Corporation Name	Corporation name of prime contractor at the time of satellite development.
Incumbent Contractor	For the prime satellite development contract: Incumbent, Change, or New start program.
Option on Prior Contract	Indicator whether the satellite build was an option on a prior contract; New Contract or Exercised Option
Competed Indicator	Competed or sole source. Note any interesting or unusual arrangements in the comments section
# of Vehicles in Contract	The total number of vehicles provided on the contract, to include exercised options

Data Fields and Definitions (3/3)

Data Field	Description
Cost Data	
NR Cost	The total nonrecurring costs of the flight system, including bus, payload, and related SEITPM. Ground system deveoplment, operations, and launch costs are not included. System of system and other miscellaneous non-flight costs such as education/public outreach were not included. Expressed in millions of FY12$.
T1 Cost	The total theoretical first unit production costs of the flight system, including bus, payload, and related SEITPM. Ground system deveoplment, operations, and launch costs are not included. System of system and other miscellaneous non-flight costs such as education/public outreach were not included. Expressed in millions of FY12$.
NR + T1 Cost	Sum of NR Cost and T1 Cost.
NR + T1 Cost Growth	The percentage growth in NR + T1 flight system cost from first documented estimate, contract or sum of contracts, or budget prior to or at PDR and final NR+T1 flight system cost documented at/after launch. Note source and details in comments section
Contract Price	The prime contract value, as opposed to the NR + T1 cost, which may include GFE or other non-contract costs. Add contracts where there are multiple primes, and note split in comment section. Express in millions of FY12 dollars
Fee	Actual fee paid, in millions of FY12 dollars
Share Ratio	Share Ratio on prime contract; if there are multiple contracts, note each in comments section
Initial Cost Data	Initial cost data from which growth is calculated; include cost, year-dollars, milestone or program event with which cost is associated, if applicable, and source date
Phased Cost Data	Costs phased, in TY$. This is a fledgling capability as we transition from storing costs in BY to TY. List year, TY cost in that year, NR or T1 or both (should be separate in each year if practical) and source
Schedule Data	
Storage or Stop-work/Stand-down Time	The amount of time, in months, lost to satellite storage or stop-work. Time is removed from development schedule prior to analysis if the time was not used for any development or test activities. This data field may eventually be replaced by calculations from the "milestones" table below.
Normalized Development Schedule Duration	The amount of time, in months, from ATP to first launch availability, if a NASA satellite, or from ATP to launch minus Storage or Stop-work/Stand-down Time, if IC or DoD. Commercial schedules are from Contract Award to Launch. This data field may eventually be replaced by calculations from the "milestones" table below.
Schedule Growth	The percentage growth in development duration from documented schedule prior to or at PDR and final schedule at/after launch.
Initial Schedule Data	Initial schedule data from which growth is calculated; include estimated ATP-Launch (or storage if storage is planned), milestone or program event with which estimate is associated, if applicable, and source date
Milestones	List each significant mission milestone, along milestone data and source/comments. Typical milestones include ATP, SRR, SDR, MCR, PDR, CDR Start System Test, End System Test, First Launch Availability, Launch, IOC, EOL.