Architecture-Level Ground Processing System Investment Model

Systems Architecture, Engineering and Cost Group

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Agenda

- Introduction
- Ground System Cost Estimating Models
- Cost Analysis Issues of Ground Processing Systems
- Technology Maturity
- Developing an Architecture-Level Model
- How the Model Works
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Introduction

- Need for a budget estimating model for future ground processing systems (10-20 years in future)
- Model to be used for Architecture-level trades
  - System details not defined yet – **VERY TOP LEVEL**
  - Current cost estimating methods required too much detail and modeling to be practical for this application
- Model must be able to forecast processing and communications share expenditures based on:
  - Several types of spacecraft, *i*
  - Number and type of spacecraft, *Ni*
  - Activation date (*Tai*) and de-activation date (*Tdi*)
  - Historical processing efficiencies and expected future efficiencies
  - Commercial best practices in processing and communications

Top Level Model for Budgets Required

Ground System Cost Estimating Models

- Several ways ground cost modeling is performed
  - Grass roots approach
    - Buildup by software, hardware and common services
    - Use of SEER, PRICE, COCOMO-II, HW Pricing forecasts, wrap factors
  - Development Models (Command & Control and Antenna Terminal)
    - Ground Cost Model (G-COST) [Ref. 1,2]
    - Fixed and Transportable Earth Station (FATES), Cost Estimating Relationships (CERs) and Cost Libraries [Ref.3]
  - Operations Models (Operations and Maintenance)
    - Mission Operations Cost Model (MOCM) and Space Operations Cost Model (SOCM) - NASA
- Pitfalls
  - Require a more detailed knowledge of ground station parameters than is typically known at the architecture planning level
  - Typically do not model mission data processing costs well

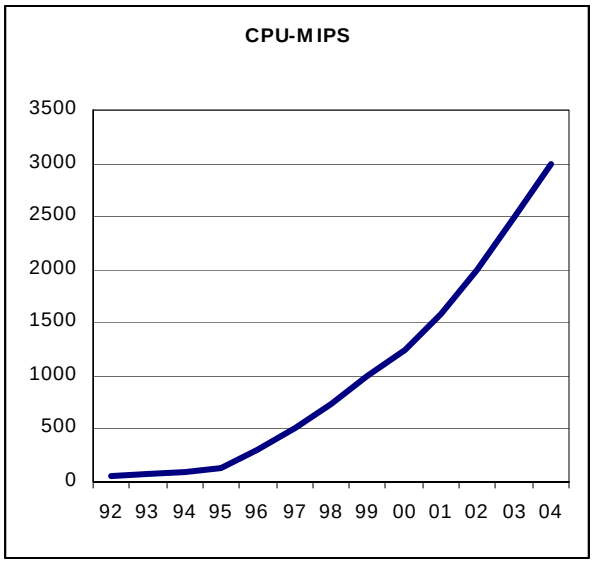
Current Cost Estimating Methods Inappropriate

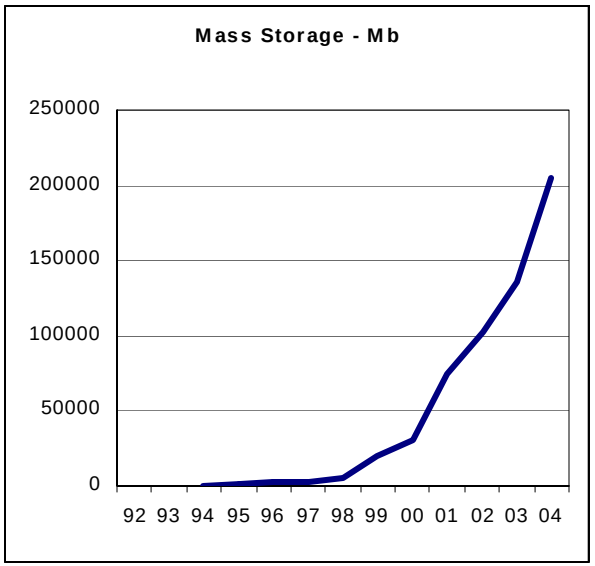
Cost Analysis Issues of Ground Processing Systems

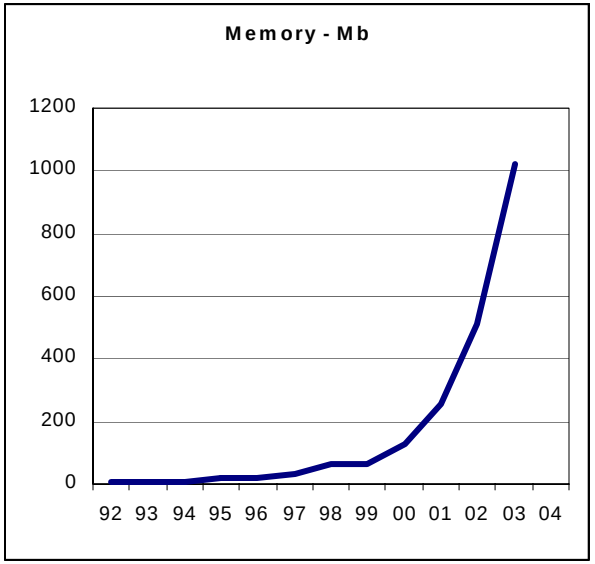
- Some ground processing systems are continuously **evolving**
  - Developed years ago
  - Continuously upgraded to handle increased satellite and mission capabilities
  - Consolidation of multiple processing sites into single site
- Difficult to develop useful cost models from the cost data
  - Obtaining “clean” actual costs
  - Establishing technology baseline to cost
  - Using historical data to predict future growth
- How do we handle things like
  - Technology Maturity?
    - Performance vs. Year for data providers (satellites) and processing systems
    - Cost vs. Year for hardware and software
  - Processing requirements based on constellation design?

Technology Maturity: Performance vs. Year

- Processor speed doubling approximately every 18 months
- Similar trends in chip memory and storage technology [Ref. 4-6]







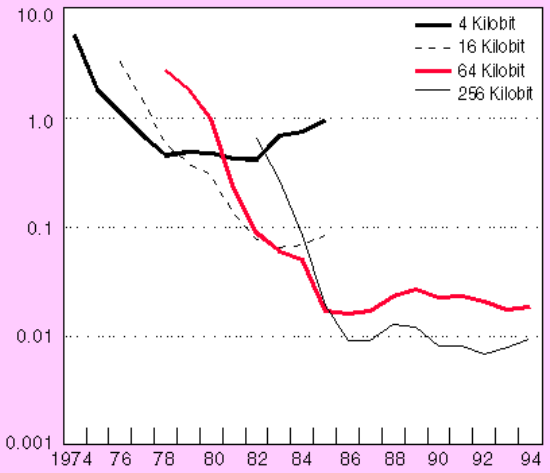
Technology Maturity: Cost vs. Year

- Processor and Memory Costs are Going Down

CHART 1

DRAM Prices Per Bit of Memory

Dollars per kilobit

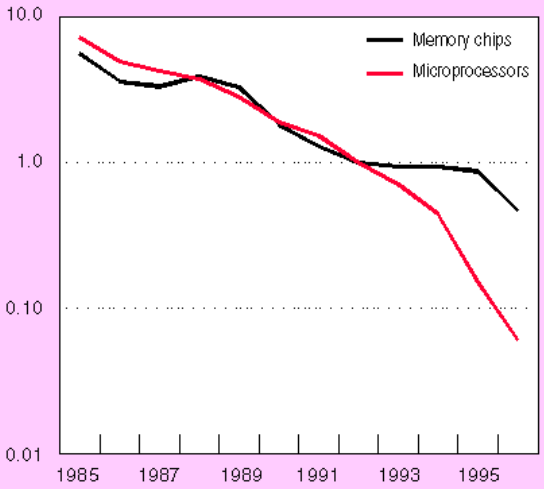


U.S. Department of Commerce, Bureau of Economic Analysis

CHART 2

Semiconductor Price Indexes

(1992=1.00)



U.S. Department of Commerce, Bureau of Economic Analysis

Developing an Architecture-Level Model

- Examined ground processing requirements vis-à-vis satellite downlink message traffic
  - If we add more satellites
  - If we use different mixes of satellites in our constellation
  - Found historical processing requirements increasing exponentially
- Examined budget actuals for customer processing and communications (1997-present)
  - Processing budget requirement increases approximately 5.7%/yr
  - Communication budget data shows similar trend
- Examined how our ground processing systems have evolved with new, more capable satellites in the constellation
  - Compared these actuals with historical processing metrics for same time period and found:
    - Processing traffic increases approximately 100%/yr
    - Communications bandwidth increases approximately 100%/yr
  - Compares well with commercial communications and processing experience

How the Model Works

Model Data

- User defines message traffic by satellite type
- Model requires investment rate and growth rates of processing and communications
- Model uses trending data to compute cost per processing and communications units

FICTITIOUS EXAMPLE ONLY

Sat Type	Message BW
<none>	0
A	5000
B	10000
C	50000
D	100000
E	500000
F	1000000
G	5000000

Historical	
Basis Year	2000
Processing Investment per year	$ 10,000,000.00
Processing Investment rate per year	5.7%
Processing volume rate per year	100.0%
Basis Message Rate, MpD	4500
Basis message cost, MpDpYr	$ 0.00045
Comunications Investment	$ 5,000,000.00
Communications Investment rate	5.0%
Communications BW rate	100.0%
Communications Basis BW, GBps	10
Basis Comm Cost	$ 0.0000020

Defining Architecture

- User defines number of satellites by type, activation year and de-activation year
- Model uses database to lookup message traffic per satellite

Satellite ID	Sat Type	Message BW	Activation Yr	Deactivation YR
a1	A	5000	2000	2005
a2	A	5000	2001	2006
a3	A	5000	2002	2007
b1	B	10000	2003	2010
b2	B	10000	2003	2010
b3	B	10000	2004	2011
c1	C	50000	2004	2011
d1	D	100000	2005	2012
d2	D	100000	2006	2013
e1	E	500000	2007	2015
e2	E	500000	2008	2016
e3	E	500000	2008	2016
f1	F	1000000	2009	2019
f2	F	1000000	2010	2020
g1	G	5000000	2012	2022

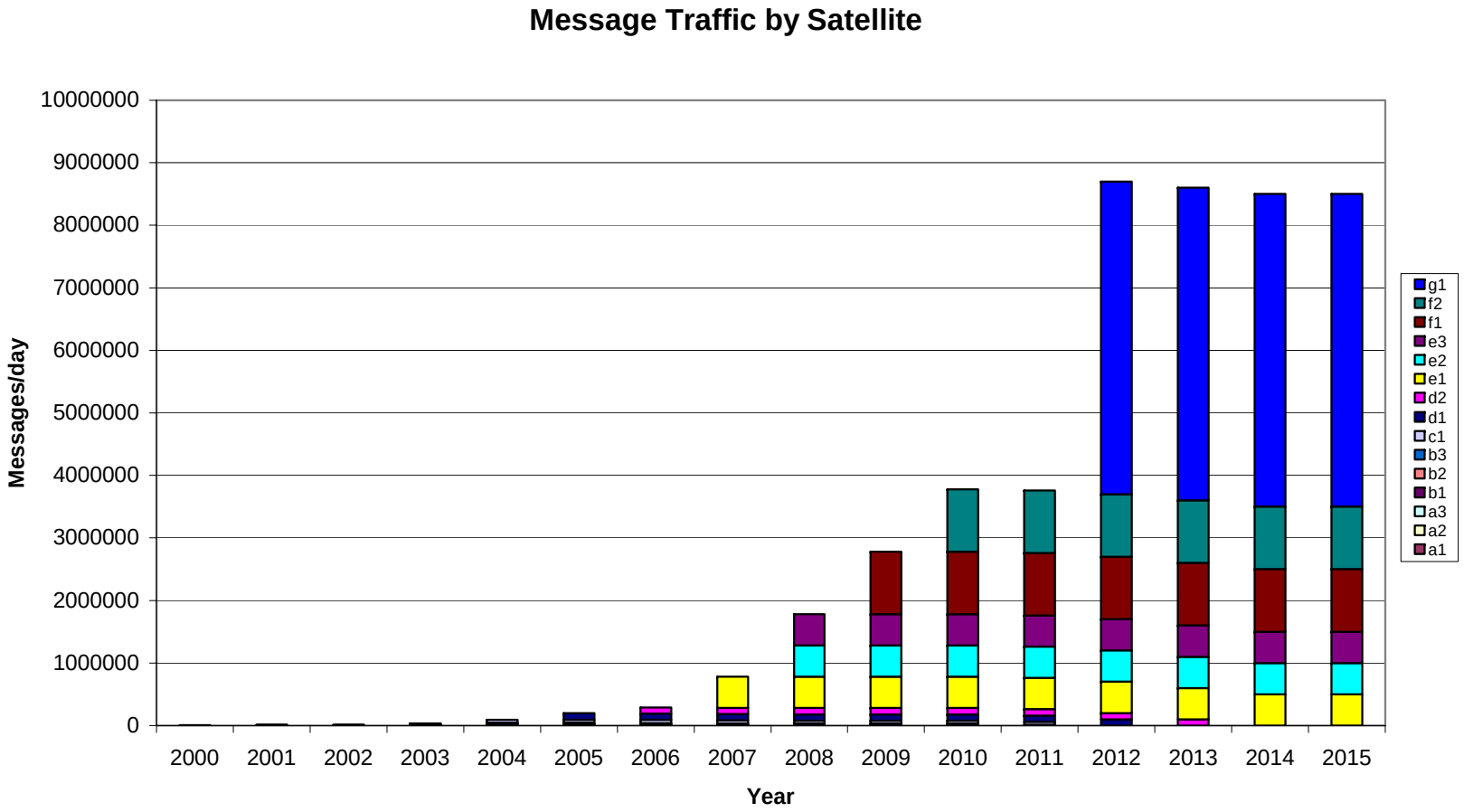
Example Constellation:
7 Satellite systems: 2000-2022
Increasing capabilities over time

- **Existing/ In development**
- **Replacement System**
- **New Systems**

FICTITIOUS EXAMPLE ONLY

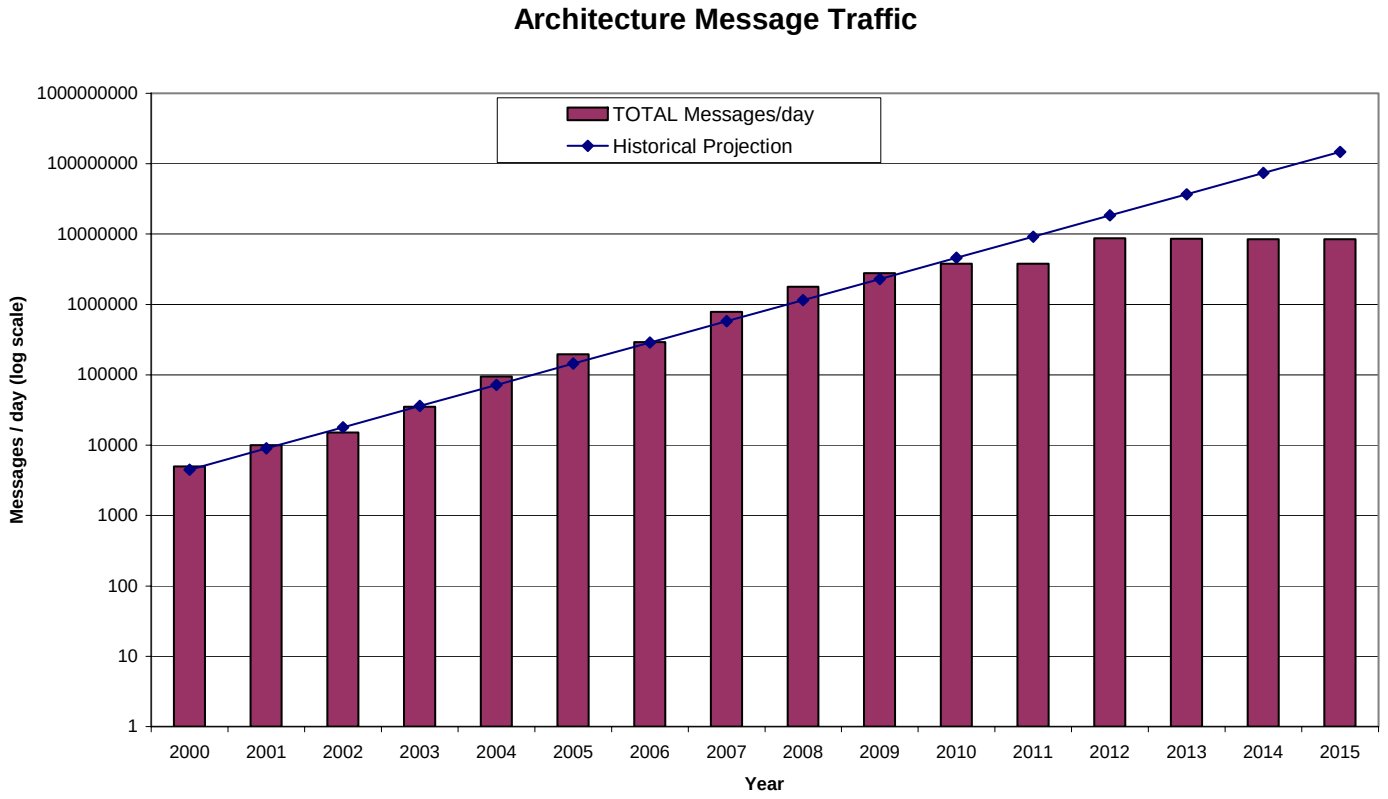
Message Traffic Trend

- Model generates message traffic trend



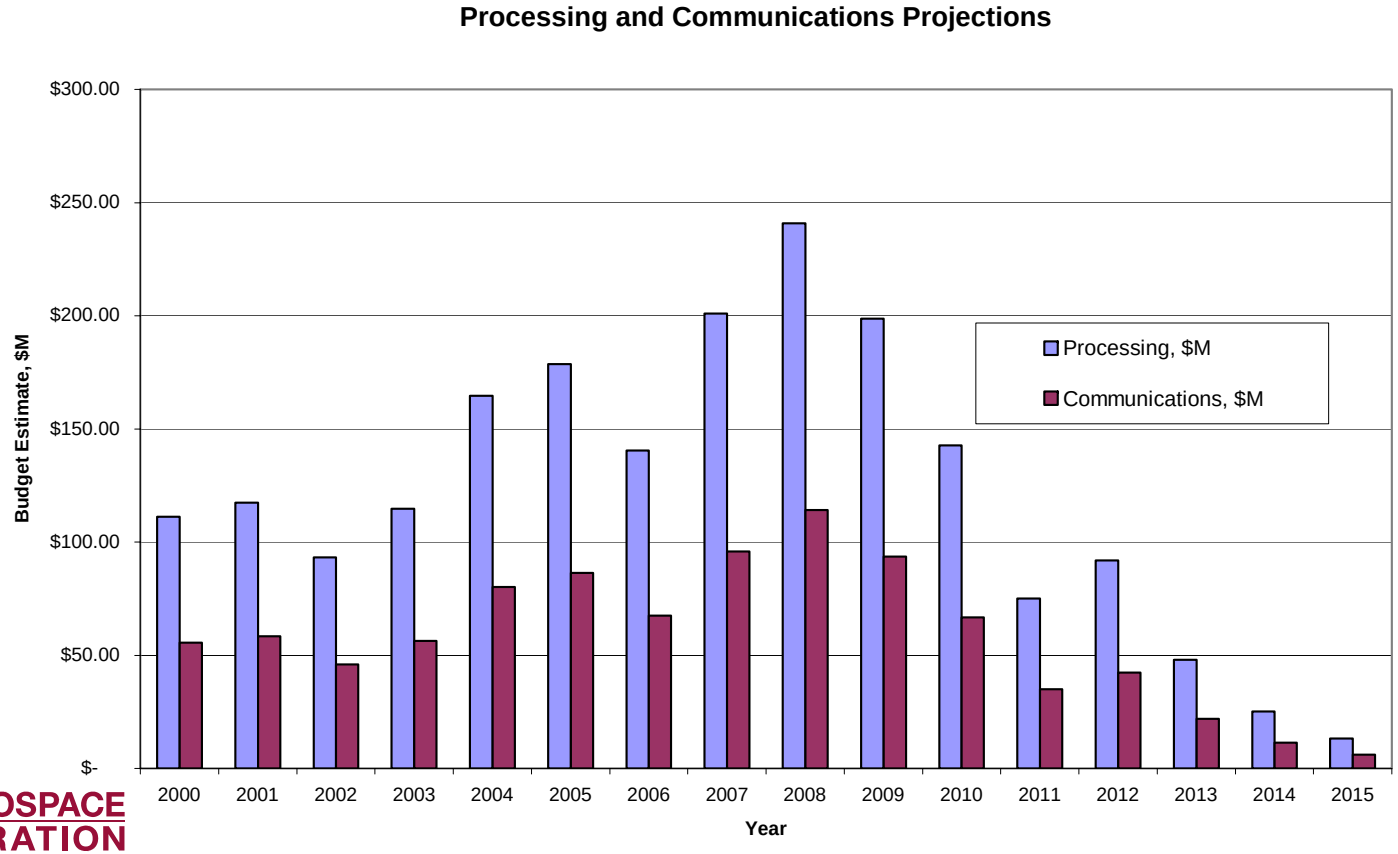
Message Traffic Trend (2)

- Model compares historical growth (fixed to investment rate) with anticipated growth due to architecture definition



Budget Results

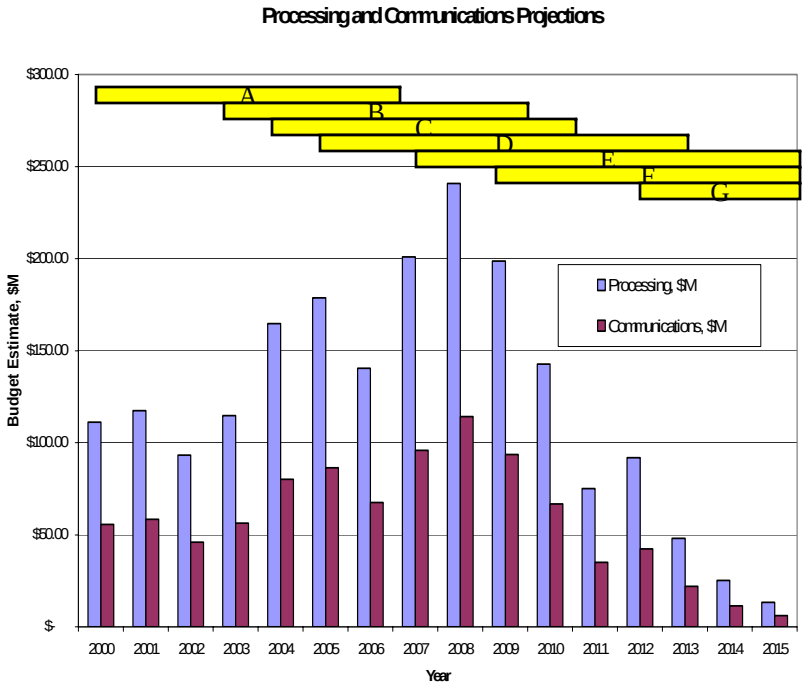
- Model develops processing and communications budget based on trend data and anticipated need based on:
  - Number and type of spacecraft, *Ni*
  - Activation date (*Tai*) and de-activation date (*Tdi*)
  - Historical processing efficiencies and expected future efficiencies



Model Results Summarized

- With the constellations, message traffic, and schedule defined, we find
  - Increased investment is required in the 2004-2008 timeframe when there are 4 active satellite systems
  - Decreased investment in 2010 - 2015 with 3 active satellite systems

Satellite ID	Sat Type	Message BW	Activation Yr	Deactivation YR
a1	A	5000	2000	2005
a2	A	5000	2001	2006
a3	A	5000	2002	2007
b1	B	10000	2003	2010
b2	B	10000	2003	2010
b3	B	10000	2004	2011
c1	C	50000	2004	2011
d1	D	100000	2005	2012
d2	D	100000	2006	2013
e1	E	500000	2007	2015
e2	E	500000	2008	2016
e3	E	500000	2008	2016
f1	F	1000000	2009	2019
f2	F	1000000	2010	2020
g1	G	5000000	2012	2022



Summary

- We have shown:
  - Very high-level architecture cost tool for ground system processing and communications budget
  - It does not provide breakout beyond budget line item level
  - It is Sensitive to portfolio selection
  - It is Sensitive to commercial and historical cost and technological trends
- Future work
  - A more detailed model that segregates cost by next one or two WBS levels for system design trades
  - Must be able to compute costs for hardware, software, and SEIT/PM.

References

1. Sidor, L.B., “G-COST 1.0 Ground Systems Cost Model Demonstration”, GSAW99 - Breakout Session 2, Los Angeles, CA, 4 March 1999.
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4. Garrett, B., “Four Forces Shape DRAM Evolution,” EE Times, 02/07/2000
5. “Status of the Industry”, Integrated Circuit Engineering (ICE), 1995.
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