



G A L O R A T H

**GSAW2001**

## **Cost Tradeoffs Between Ground & Space**

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# Abstract

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- **CAIV (Cost As an Independent Variable) should be integral to any discussion of the viability of future architectures as functionality is migrated from ground to space, and as autonomy is increased both in space and on the ground**
  - Autonomy has a price that must be computed before a new architecture is adopted
  - Total system tradeoffs are needed to minimize resources needed to implement new operational concepts as space and ground systems are configured to support them
  - The authors will show how the SEER family of cost estimating models can be used to perform these tradeoffs
  - As part of this presentation, they will also demonstrate how the architectural risk of proposed configurations can be quantified in terms of cost and schedule impacts



# Scope

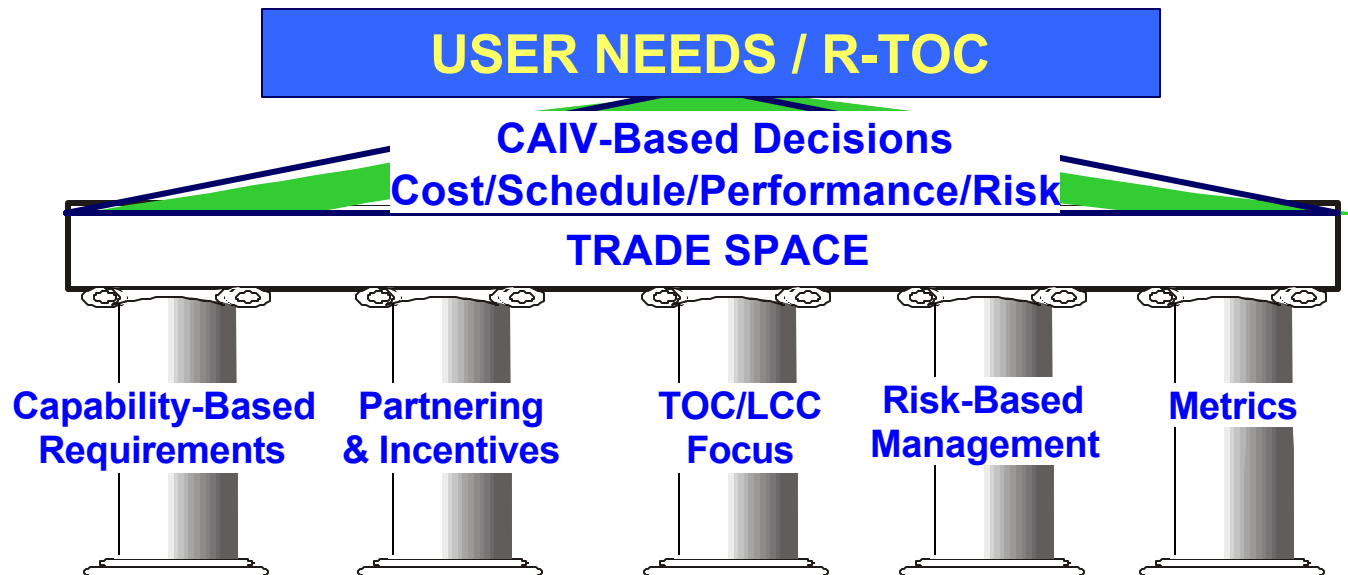
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- **This paper focuses on cost tradeoffs between ground and space hardware and software**
  - It is our contention that functionality will be migrated from the ground to space when it makes economic sense to do so
- **Non-cost operational benefits of autonomy and migration of functionality from ground to space are not considered**
  - In the CAIV paradigm, they could potentially be sacrificed for the sake of affordability
  - Not considered are issues of timing, data quality, availability and other factors that could make autonomy appropriate even at extra cost
- **The presentation demonstrates the feasibility and utility of the trades, using the SEER family of estimating tools**



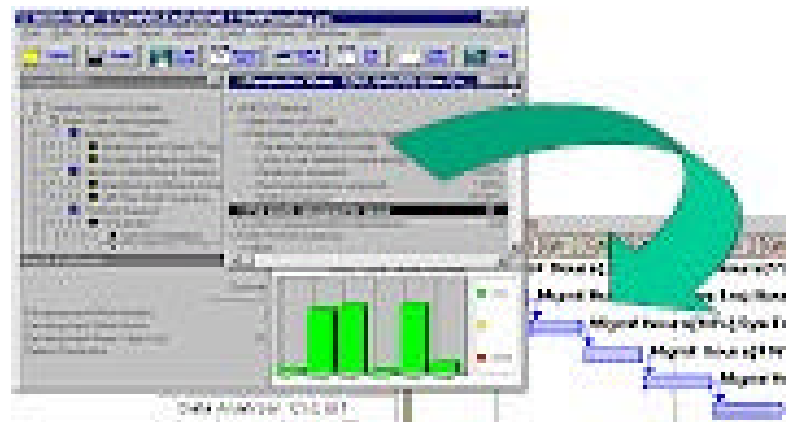
# CAIV Elevates Cost To a Mission Success Factor

- Performance & schedule are dependent on funds available
- The purpose of CAIV is to:
  - Reduce life cycle costs
  - Reduce development and production time
  - Increase innovation in design, manufacturing, support, and contracting
  - Overcome program cost growth



# CAIV Process Considerations

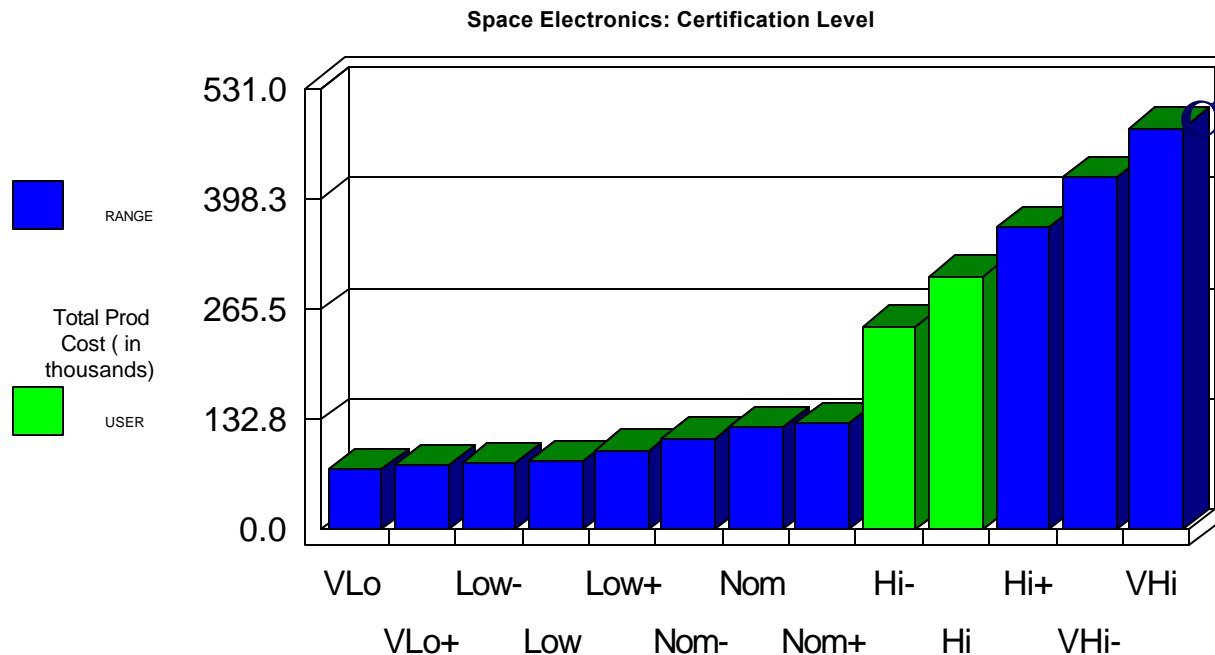
- **Highly analytical and technical**
- **Requires:**
  - Ability to trade requirements against costs and schedules
  - Skilled / experienced people
  - Sophisticated analysis tools
  - Management and team commitment
  - Integration into and rewarded within the contract structure so that all parties are properly motivated



# Typical Cost Increases From Ground To Space Electronics

## •SEER-H Knowledge Bases Generated Estimates

	Space	Ground	Increase
<b>Development Cost</b>	<b>\$1,951K</b>	<b>\$343K</b>	<b>+469%</b>
<b>APUC (10 Units)</b>	<b>\$429K</b>	<b>\$136K</b>	<b>+314%</b>

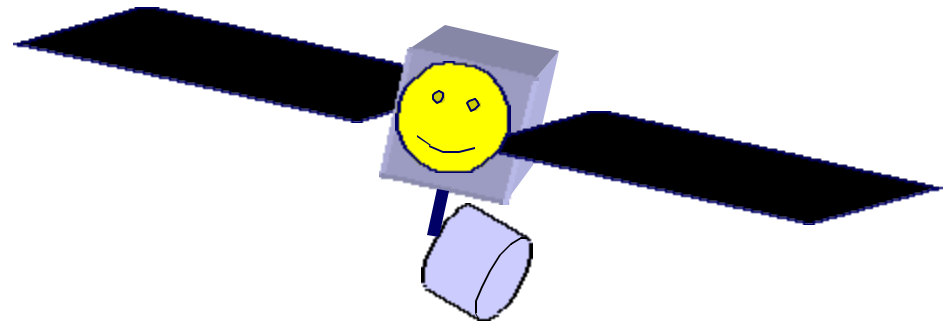


**Migration of  
hardware to  
space is  
expensive!**

# Software Autonomy Trades Involve Hardware vs Software

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- **Autonomy means higher SLOC counts and increased complexity**
- **Higher SLOC counts imply more:**
  - Memory
  - Processing power
  - Weight
- **Savings from autonomy**
  - Less man-in-the-loop (reduced operating costs)
  - More standardization and reusable code
  - Less bandwidth



# Ground Based Functions Are Normally Cheaper Than Space Based

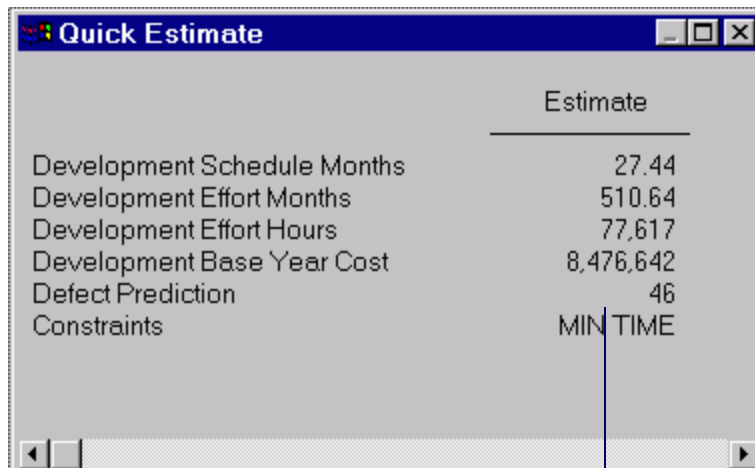
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- **Past practice:**
  - Ground based management of many spacecraft activities
  - Spacecraft must provide most of the information (communications / bandwidth intensive)
- **New trend:**
  - More spacecraft autonomy using increased data system capabilities (CPU, I/O, storage, etc.)
- **Key advantages of autonomy**
  - Reduced operating costs
  - Ability to perform new missions with increased reliability (constellation management, etc.)
- **Moving functionality to space can be expensive**
  - Software is more constrained and complex
  - Therefore, it is more expensive



# Ground Based Functionality Can Generally Be Built On A Tighter Schedule & Cost

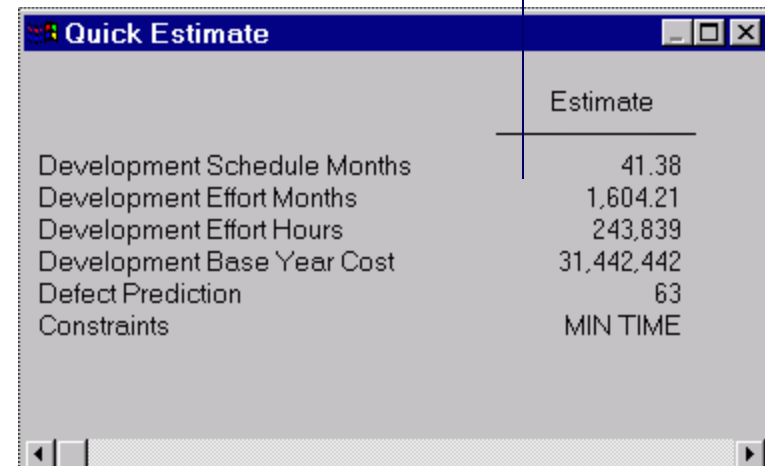
- Used SEER Knowledge Bases To Model Identically Sized Software On Ground and In Space



	Estimate
Development Schedule Months	27.44
Development Effort Months	510.64
Development Effort Hours	77,617
Development Base Year Cost	8,476,642
Defect Prediction	46
Constraints	MIN TIME

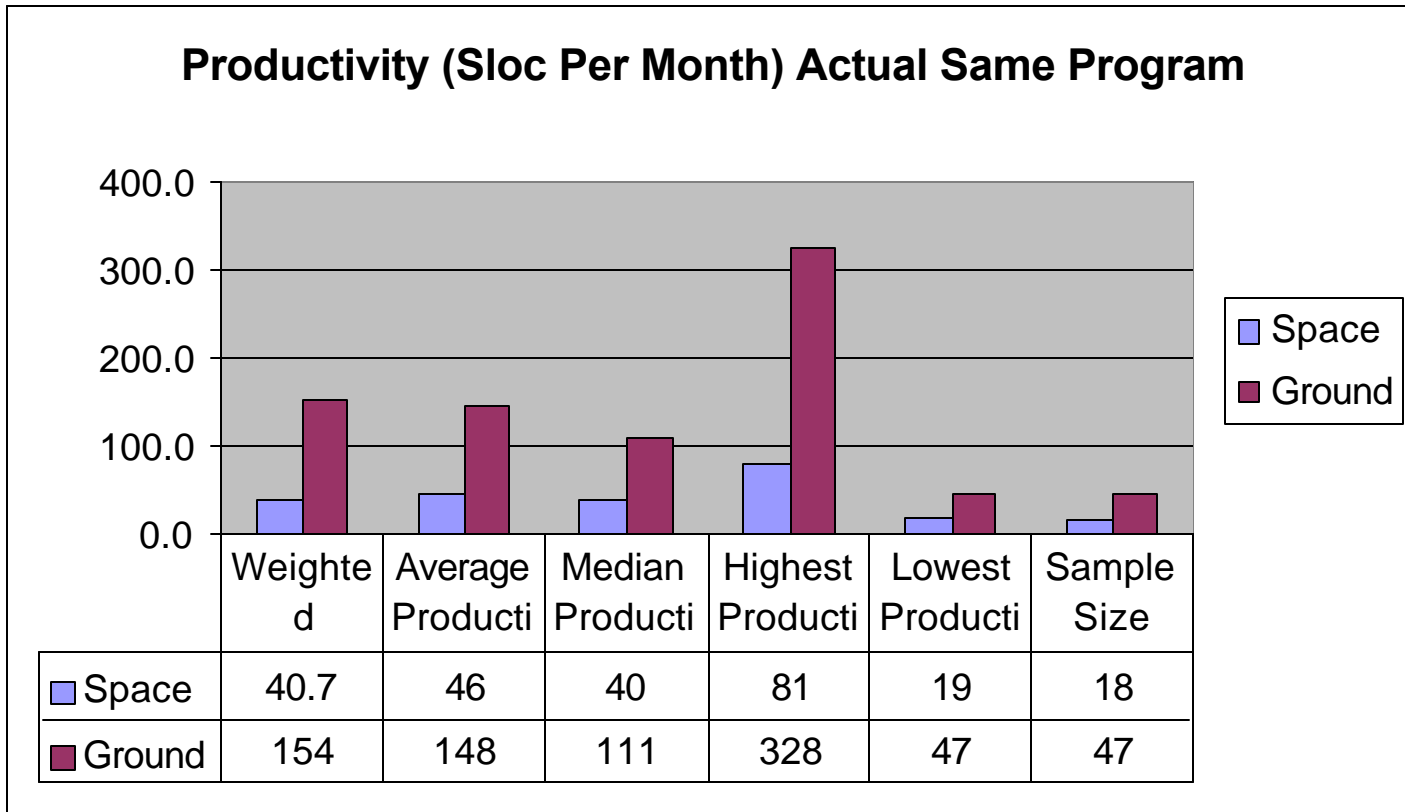
**Ground System,  
50,000 SLOC  
27 Months  
\$9M**

**Space System,  
50,000 SLOC  
41 Months  
\$31M**



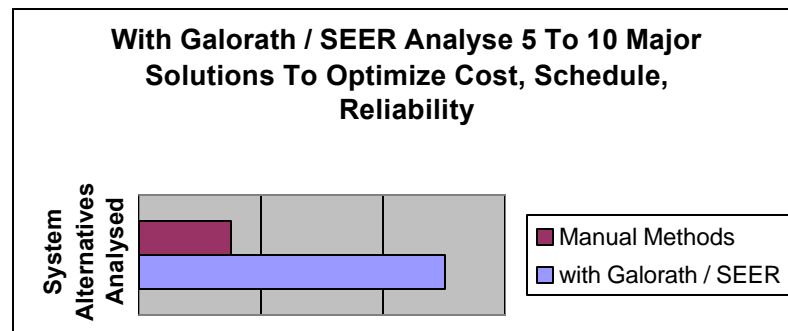
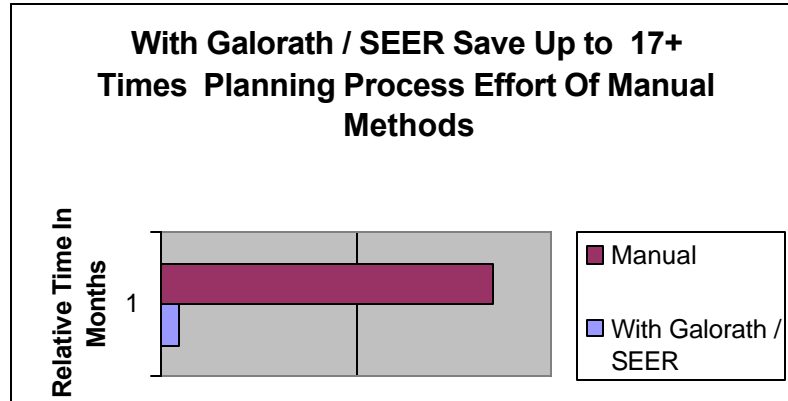
	Estimate
Development Schedule Months	41.38
Development Effort Months	1,604.21
Development Effort Hours	243,839
Development Base Year Cost	31,442,442
Defect Prediction	63
Constraints	MIN TIME

# Actuals Compared Ground Vs Space Same Program



# Cost Models Reduce Trades Effort... Increase Number of Trades Possible

Source: Hughes, Case, Others



- SEER Provides a 17 to 1, to 20 to 1 time savings in planning process over manual methods cost proposals / CAIV efforts, etc.

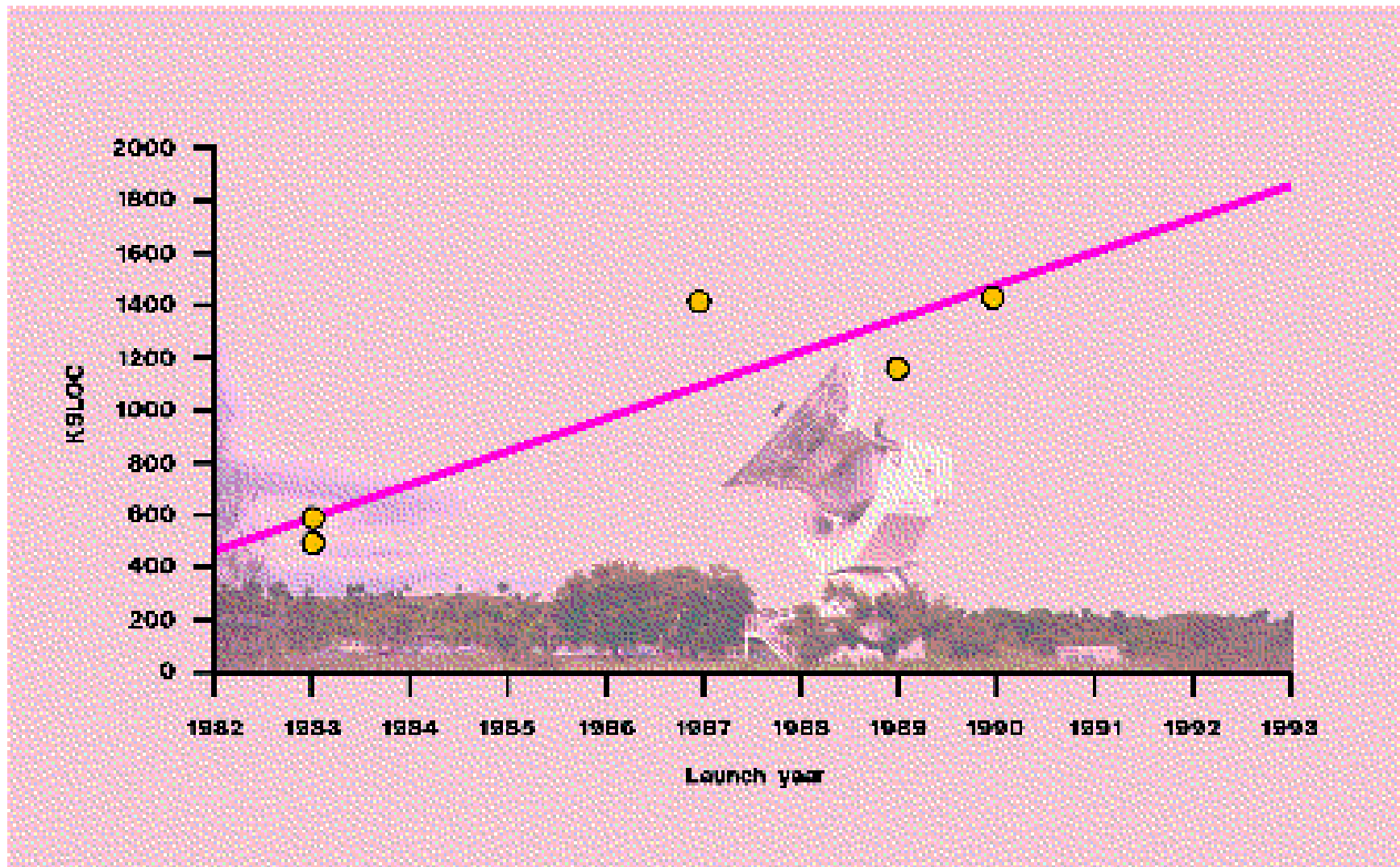
- Organizations can analyze 5 to 10 major solutions to optimize on cost, schedule, reliability

- SEER identifies candidates for cost avoidance / reduction

“Traditional industry practices often mean a part or assembly in early evaluation stages has to be sent out for several bids - a two to three week process. With SEER, I can work with an engineer to specify a part’s cost in 10 minutes” Michael Walter, Advanced Manufacturing Group, Case Corp.

# Software Continues to Grow in Space Programs

Source ESA



# Conclusions

- **More Major Systems Require Cost Be Considered Part of the Design Trades**
  - Need to analyze situation thoroughly before migrating functions to space to take cost/schedule tradeoffs into account
- **Space Hardware and Space Software Continue To Cost Significantly More Than Ground**
  - Must look for innovative ways to take advantage of economies (product line architectures, etc.)
- **There Are Good Technical Reasons For Space Based Autonomy**
- **CAIV May Highlight Some Cost and Schedule May Change Some Architectural Decisions**

