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Independent Parametric Cost Assessment
Ikonos II Optical Sensor Assembly
and
Cost as an Independent Variable (CAIV) Approach
for
Eastman Kodak Company

May 25, 2001

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Presentation Outline

- CAIV Concepts
 - Approach
 - Systems cost effectiveness
- Assessment of Eastman Kodak performance
 - Evaluation of Ikonos-I operational performance
 - Assessment of Ikonos-I cost performance
- Preliminary estimate of Ikonos-II cost

CAIV Concepts

(Cost as an Independent Variable)

Systems Cost Effectiveness

- A cost effectiveness study analytically assesses the comparative worth of alternatives for achieving a designated goal through the joint consideration of costs, time, technical performance, and limitations. Cost effectiveness considerations are associated with system trade-offs.
- Cost effectiveness procedures include
 - Definition of program or system objectives
 - Identification of a set of alternatives for meeting system objectives
 - Development of measures and techniques, preferably quantifiable, for measuring the effectiveness and cost of alternatives
 - Calculation of the comparative effectiveness and costs for each alternative
 - Provision for combining cost-effectiveness into a single measure
 - Analysis of cost-effectiveness findings, including selection of the most promising alternatives and elimination of the least promising
 - Design of new alternatives that offer greater effectiveness than those selected above
 - Identification of cost effectiveness trade-offs offered by the selected alternatives

AFSCM 173-1 April 17,1972

Assessment of Eastman Kodak Performance f (Ikonos-I)

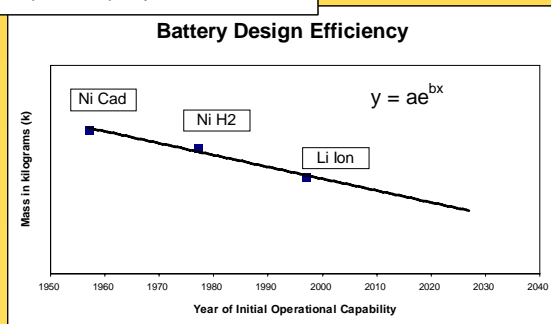
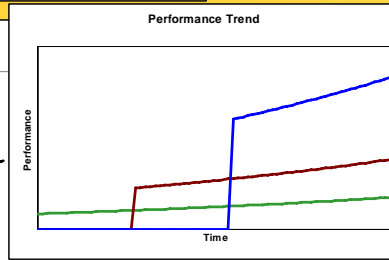
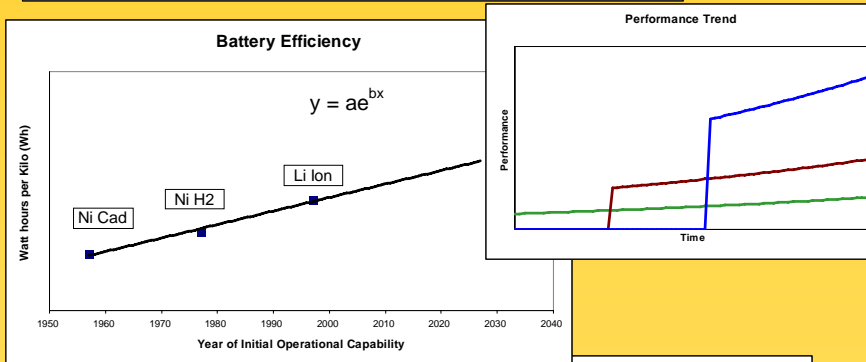
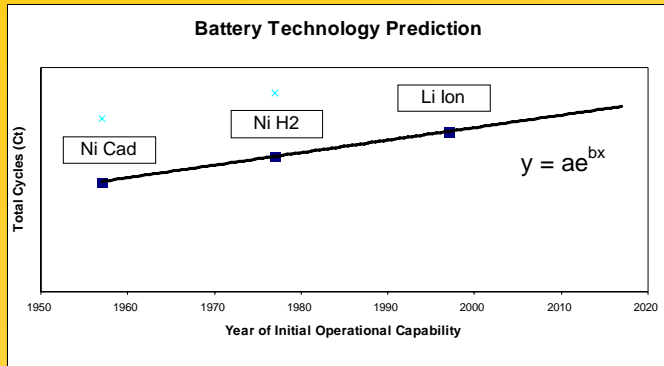
Methodology

- Use time as the primary determining factor
- Relate time to:
 - Cost variables
 - Risk and technology
 - Program characteristics
 - Improvements in methods and processes-general
 - Performance
 - Output (computational power, recharge cycles, range, etc.)
 - Performance Efficiency (energy conversion)
 - Accuracy (drift rate, resolution)
 - Design Efficiency
 - Cost complexity (MCPLXe/s)
 - Specialized design and manufacturing tools
- Cost and performance is directly associated with time
(technological availability)

Cost Considerations

- Current Technology Comparison to Future Technology
- Cost Historical Data for Current Technology
- Technical Considerations for Current Technology and Future Technology
 - Engineering Effort
 - Engineering Difficulty
 - New Design Effort
 - Technology Indices
 - Design Integration
 - Time (Technology Year)
 - Maturity Level
 - Improvements in Methods and Processes
 - Technology Trends in engineering parameters

Technology versus Time



Most component technologies historically have maintained consistent improvement rates in

Performance

(batteries; cycles)

Efficiency

(batteries; watt-hours per kilogram)

Physical characteristics

(batteries; total kilograms, density, and volume)

Technological cycle time is consistent and driven by

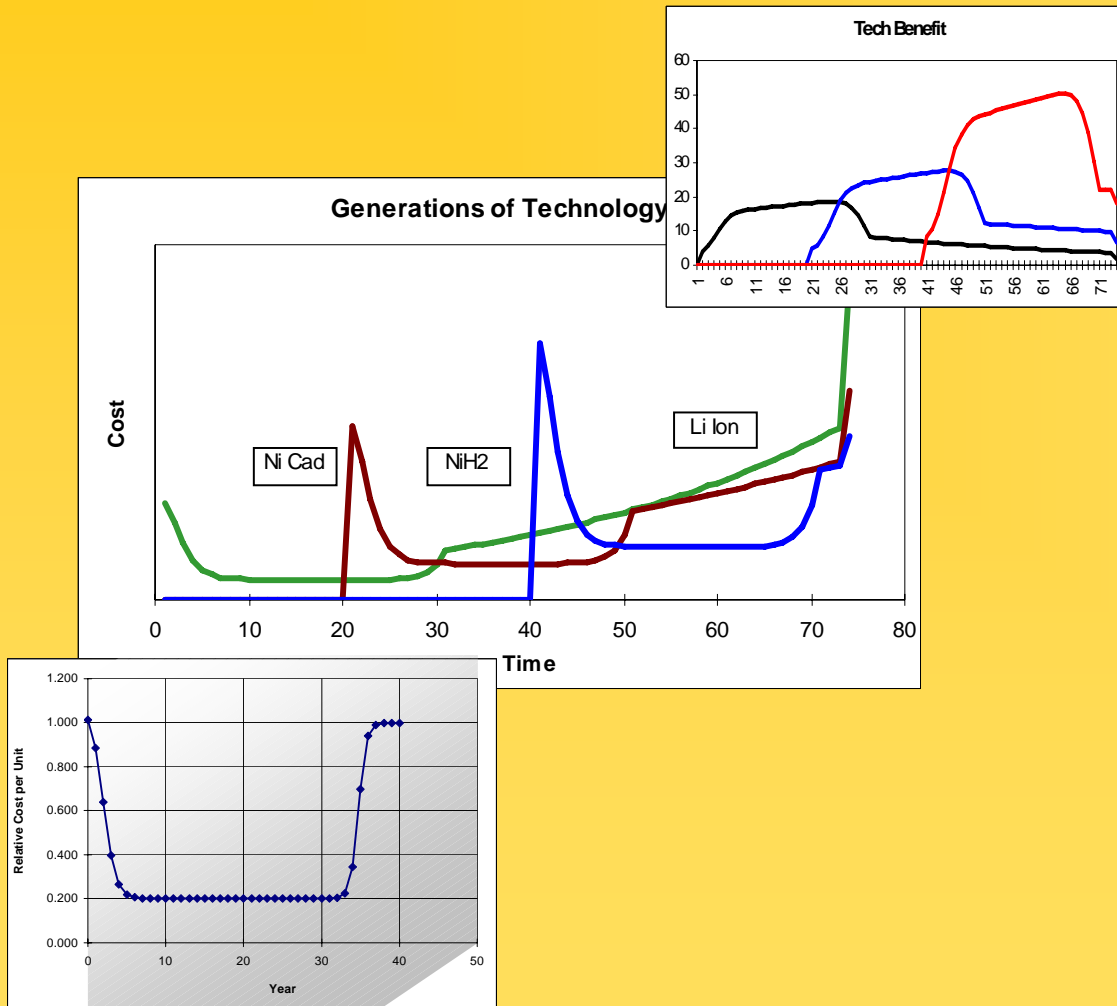
Application

Competition

Demand

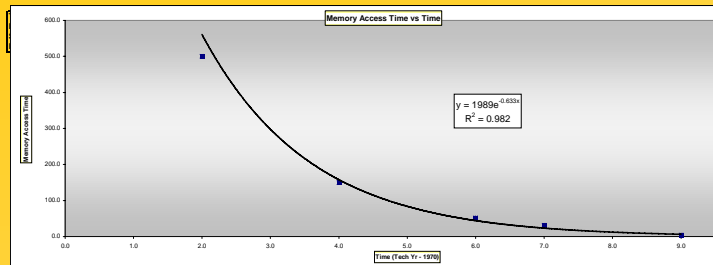
Subsidiary industries

Generations of Technology



- Three generations of technology depicted
- Initial high peaks of each generation caused by subcontractor processes maturity costs, prime contractor design integration costs and low producibility
- When obsolete for several generations, cost is higher than current technologies of much greater performance

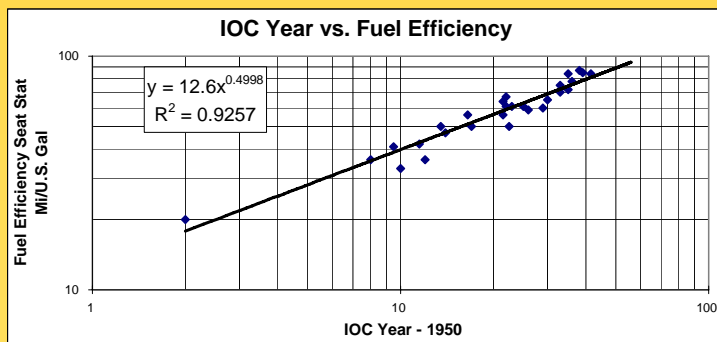
Examples of Technology Time Trending



Reference	Model	1970 Time X(Tech Yr - 1970)	Memory Access Time Y(Yrs)	Data Used	Pred Y(Yrs)	Error Y(Yrs)	Ratio
Electronics, 9/13/79, p. 126	2.102E0	2.0	500.0	Yes	560.77	60.77	1.12
Electronics, 9/13/79, p. 126	2102A	4.0	150.0	Yes	158.10	8.10	1.05
Electronics, 9/13/79, p. 126	2.115E0	6.0	52.0	Yes	44.57	-7.43	0.86
Electronics, 9/13/79, p. 126	2115A/2125A	7.0	32.0	Yes	23.67	-8.33	0.74
Electronics, 9/13/79, p. 126	2125H	9.0	5.0	Yes	6.67	1.67	1.33
		28	739	5	Expon	17.26	

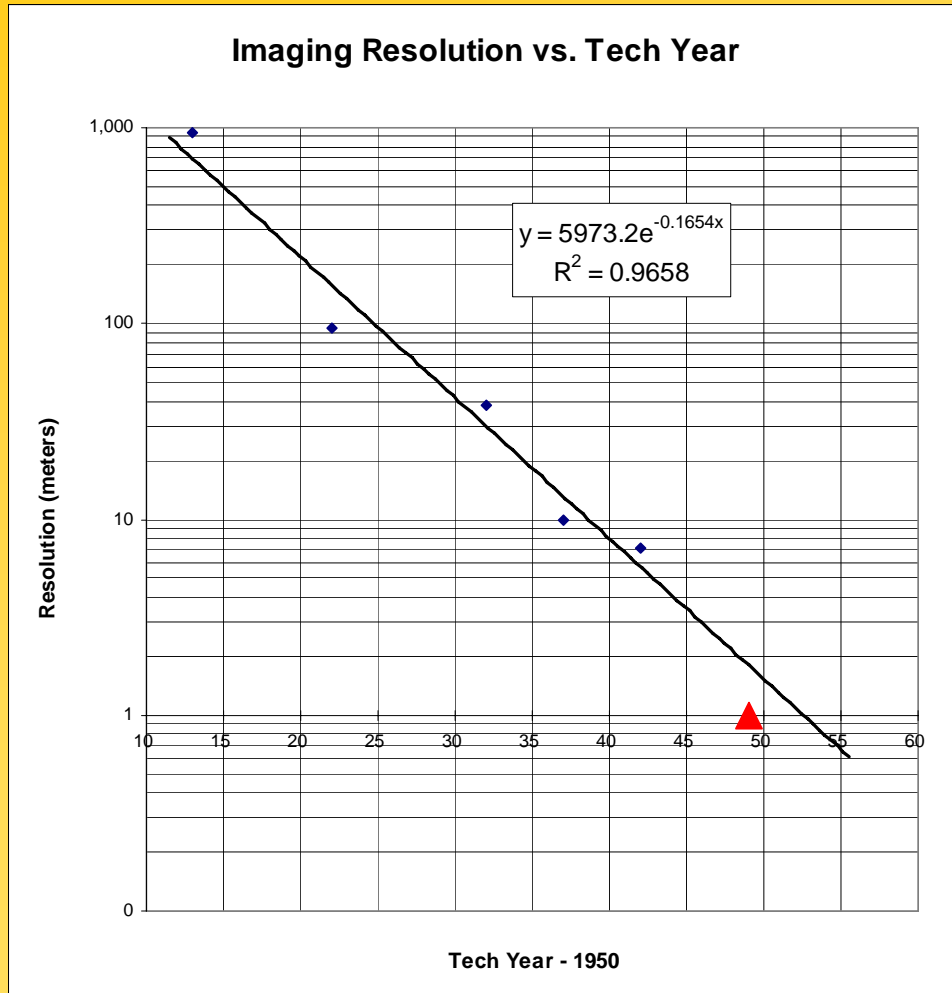
ALGORITHM FORM	X	Y	R ²	Form Select	Intercept A	Slope B
Linear	y=at+b	lin	0.786	0	523.1918	-67.0342
Expon	y=a*b ^x	lin	0.982	1	1.969.0224	-0.6330
Power	y=a*x ^b	log	0.899	0	4.988.4261	-2.7853
Loath	y=a*b ^{1/x}	log	0.932	0	665.8064	-335.6525

Analysis: Fuel Efficiency (FE) vs IOC
Systems: Aircraft, Commercial



- Many previous technical publications have established the relationship between time and performance.
- Increases in performance over time are very consistent over long periods.
- MCPLXe/s values represent increases in performance and capability.
- Slowing of rate in change indicate obsolescence.
- Predictions with upward variances in performance are good indicators of technical, schedule and cost risk.
- Technological approach is rarely changed but has occurred.
- Components, subsystems and systems follow the same patterns.

Assessment of Ikonos-I Performance Imaging Resolution



- Leading performance improvement rate is stable
- Ikonos-I achieved a performance of accelerated technology application
- Accelerated by 3-4 years
- Rarely seen

Optical Challenges

Ikonos I

Characteristics	Primary	Secondary	Tertiary
Type		Solid	Solid
Shape	Concave Elliptical	Convex Hyperbolic	Concave Elliptical
Off Axis	n/a	n/a	Kodak First
Size Experience	normal	Small	Small
Aerial Density	Stress	typical	typical
Quality of Surface	0.019	.01=2x	.01=2x
Test Scheme	Standard	Hindleshell (understood)	Null Holographic (new)
Asperical Departure	Heritage	Severe	Very Severe
	3	6	13 22

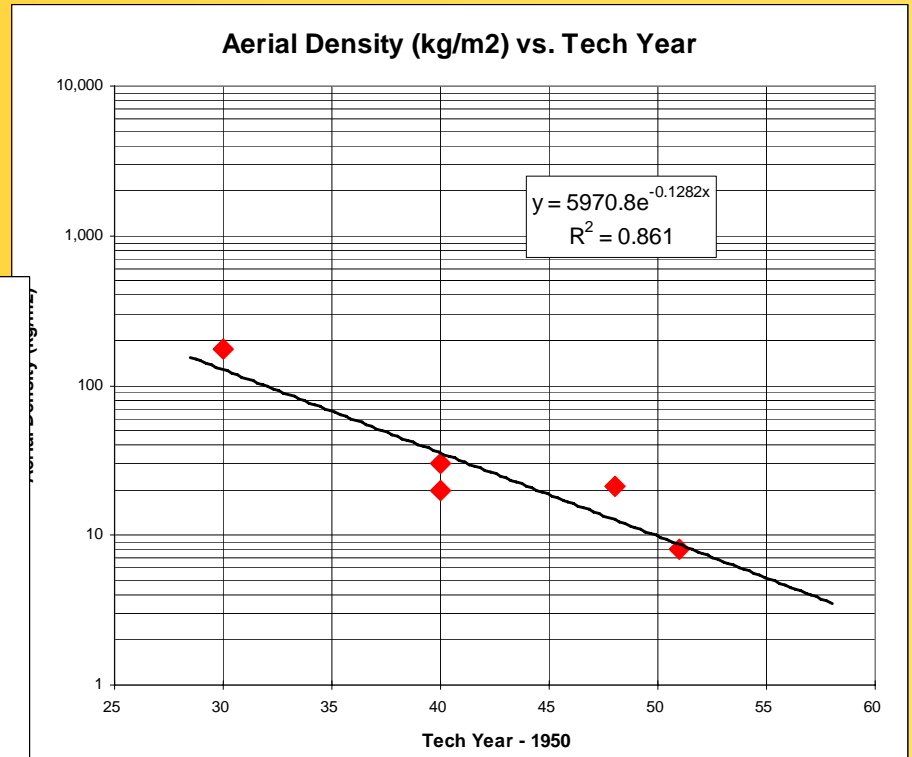
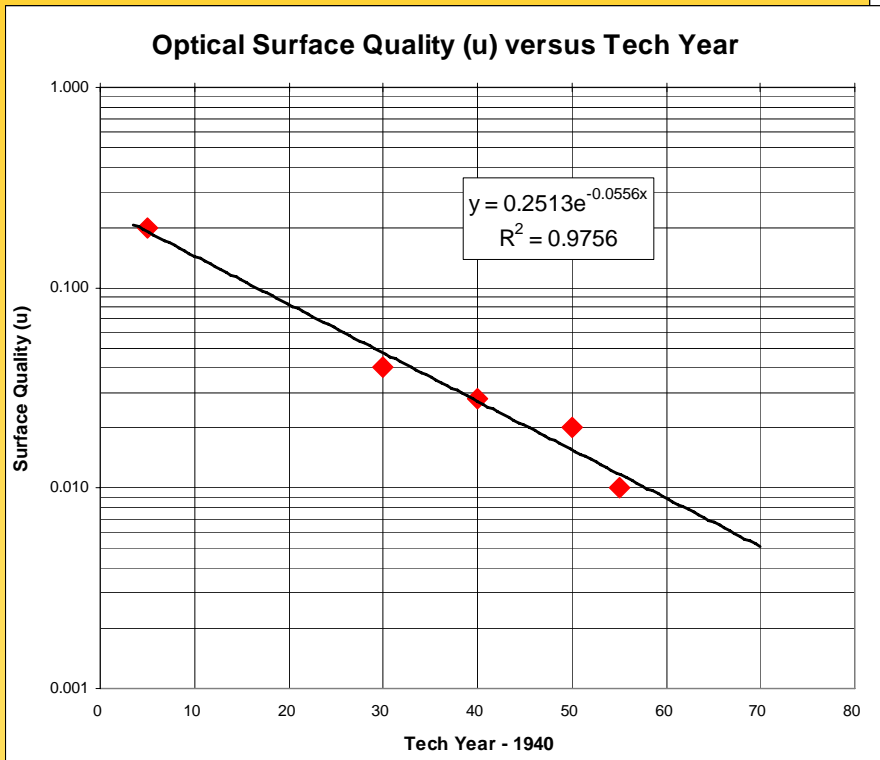
Ikonos II

Characteristics	Primary	Secondary	Tertiary
Type		Solid	Solid
Shape	Concave Elliptical	Convex Hyperbolic	Concave Elliptical
Off Axis	n/a	n/a	Limite4
Size Experience	normal	Small	Small
Aerial Density	Stress	typical	typical
Quality of Surface	0.019	Limited	Limited
Test Scheme	Standard	Hindleshell (understood)	Null Holographic (new)
Asperical Departure	Heritage	Severe	Very Severe
	3	4	8 15

1
2
3

- Cost model variables reflect specific challenges

Aerial Density (kg/m²) and Optical Surface Quality



Cost Model Simulation

PRICE Estimating Suite 2000 - SR5 - [C:_Webb\A-Kodak\ikonos-1c-h.hpr]

File Edit View Format Util Window Run! Help

Category	Item ID	Description	HL	Print	GLB	ESC	FIN	DEP
	0	Sys ikonos-1 Optical Sensor Calibration						
Assembly	1	OTU- Optical Telescope Unit	HL					
Electronic	2	FOA- Fwd Optical Assy	HL					
Struct/Mech	3	FMS - Fwd Metering Str	HL					
Purchased	4	CA- Calibration Unit	HL					
Furnished	5	SMA- Secondary Mirror Assy	HL					
Modified	6	Mirror, Secondary	HL					
Mod/Chip	7	Str, Reaction, SMA	HL					
Design Integ	8	SMA- I&T	HL					
Hw/Sw Int	9	ARD- Alignment Ref Device	HL					
Integ & Test	10	FB- Fwd Baffles	HL					
Calibration	11	Str- FOA	HL					
Thruput	12	FOA I&T	HL					
Multiple Lot	13	AOA- Aft Optical assy	HL					
	14	PMA- Primary Mirror Assy	HL					
	15	Mirror, Primary	HL					
	16	Str, Reaction,PMA	HL					
	17	PMA I&T	HL					
	18	TMA- Tertiary Mirror Assy	HL					
	19	Mirror, Tertiary	HL					
	20	Str, Reaction, TMA	HL					
	21	TMA I&T	HL					
	22	FMA- Folding Mirror Assy	HL					
	23	Mirror, Folding	HL					
	24	Mirror, Folding	HL					
	25	Mirror, Folding	HL					
	26	Str, FMA	HL					
	27	FMA I&T	HL					
	28	AMS- Aft Metering Str	HL					
	29	AB- Aft Baffles	HL					
	30	AOA I&T	HL					
	31	Cables	HL					

PRICE Estimating Suite 2000 - SR5

Cost Model Simulation

STRUCTURAL / MECHANICAL

Str- FOA

OK
Cancel

Input Form | LM Sheet | ID Sheet | Risk Input | Distributions | Worksheet

Validate | Notepad | Override | Reset | Schedule | Help

QTY	PROTOS	WT	VOL		
0	2.07	28.7100000	0.50000		
QTYNHA	INTEGE	INTEGS	PLTFM	YRTECH	
1	0.0000	1.0000	2.000	0	
WS	MCPLXS	NEWST	DESRPS	MREL	
28.7100000	7.304	1.000	0.000	0.00	
DSTART	DFPRO	DLPRO	ECMLPX	DTLGTS	PROSUP
195	797	1297	0.70	0.00000	1.00
PSTART	PFAD	PEND	MPI	PTLGTS	RATOOL
0	0	0	0.0000	0.00000	0.0000000

MCPLXS Generator

ion:

d

m machined parts in assembly

ange:

00 lb / 20 - 200 kg

aterial:

Composites, Glass, Ceramics

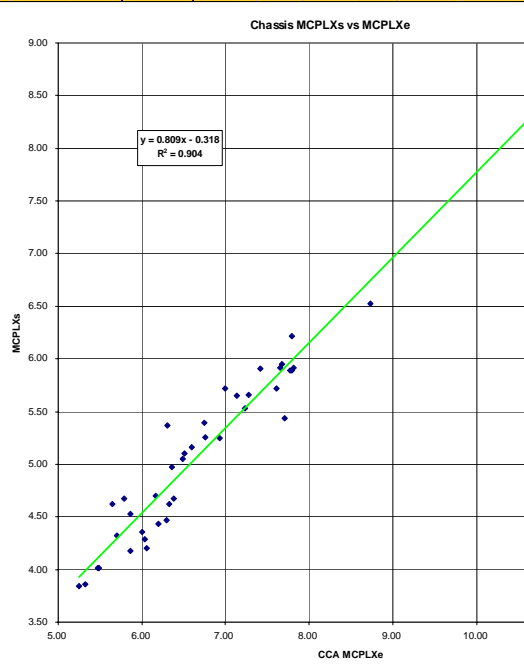
Parts/Machinability/Pltfm

	PRICE	Input
TFM	2.000	0.000
arts:	500	0
chin	5	0
tor:		0.000
PLXS:		0.000
ted MCPLXS:		7.592

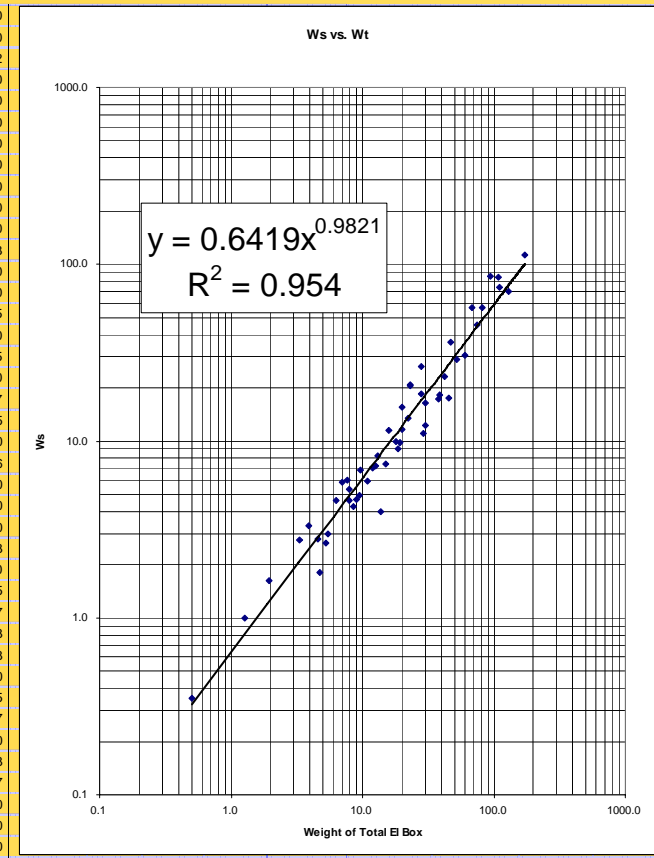
Calculate | OK | Cancel

Cost Model Calibration

	Mc	Ms	Used	y	y	Ratio
Receiver 1	5.70	4.32	Yes	4.27	-0.05	0.99
Receiver 2	6.00	4.36	Yes			
Receiver 3	6.60	5.16	Yes			
Receiver 4	6.38	4.67	Yes			
Receiver 5	5.25	3.84	Yes			
Receiver 6	6.29	4.47	Yes			
Xmtr 1	6.33	4.62	Yes			
Xmtr 2	6.06	4.20	Yes			
Xmtr 3	5.65	4.62	Yes			
Xmtr 4	5.86	4.53	Yes			
Control 1	5.47	4.01	Yes			
Control 2	5.48	4.01	Yes			
Control 3	5.32	3.86	Yes			
Control 4	5.79	4.67	Yes			
Control 5	7.42	5.91	Yes			
Control 6	7.14	5.65	Yes			
Control 7	6.76	5.26	Yes			
Control 8	7.61	5.72	Yes			
Control 9	6.16	4.70	Yes			
Transcvr 1	8.73	6.52	Yes			
Transcvr 2	6.93	5.25	Yes			
Transcvr 3	7.23	5.53	Yes			
Transcvr 4	7.81	5.92	Yes			
Transcvr 5	7.68	5.95	Yes			
Transcvr 6	7.79	5.89	Yes			
Transcvr 7	6.20	4.43	Yes			
Transcvr 8	7.77	5.89	Yes			
Transcvr 9	5.86	4.18	Yes			
Transcvr 10	6.04	4.29	Yes			
Transcvr 11	7.79	6.22	Yes			
Transcvr 12	6.75	5.39	Yes			
Transcvr 13	6.49	5.05	Yes			
718F-1 RT	6.51	5.10	Yes			
718M2 RT	6.99	5.72	Yes			
HF Comm U-2	6.31	5.37	Yes			
HF Comm U-4	7.65	5.92	Yes			
PRC-515 RT	7.71	5.44	Yes			
Translator	6.36	4.97	Yes	4.86	-0.11	0.98
Indicator	7.28	5.66	Yes	5.60	-0.06	0.99

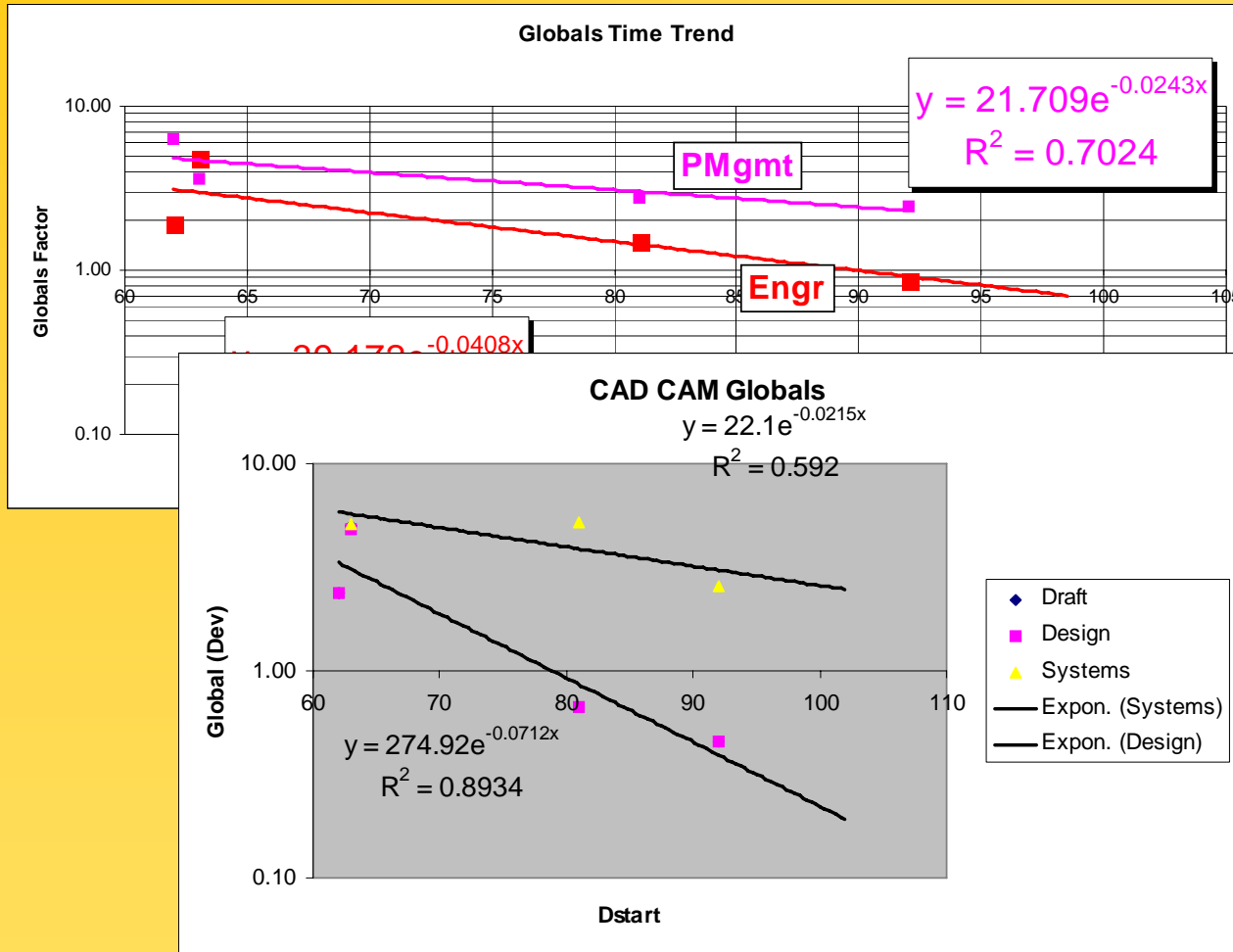


Rcvr-5	1.0	20.0
Rcvr-4	1.0	28.0
Rcvr-6	1.8	30.2
Rcvr-1	1.0	38.0
Tmscvr-1	1.0	16.0
Tmscvr-2	1.0	29.0
Tmscvr-3	1.0	94.0
Tmscvr-4	1.0	68.0
Tmscvr-5	1.0	18.0
Tmscvr-6	1.0	52.0
Tmscvr-7	1.8	75.0
Tmscvr-8	1.8	5.3
Tmscvr-9	1.8	110.0
Tmscvr-10	1.8	9.0
Tmscvr-11	1.8	8.5
Tmscvr-12	1.8	13.0
Tmscvr-13	1.8	9.5
Tmscvr-14	1.8	15.0
Tmscvr-15	1.8	4.7
Tmscvr-16	1.8	5.5
	1.8	108.0
SDMA	1.4	4.6
CIE	1.8	130.0
	1.8	47.0
DCEA	2.0	30.0
FSDU	2.0	22.3
NDU	2.0	45.0
ITS/RFDU	2.0	18.5
RFS	2.0	9.7
L3 Transmitters	2.0	6.3
Spit Sun Sensors	2.0	1.3
Cesium Freq Std	2.0	28.0
Current Sensors	2.0	0.5
DC/DC Converter	2.0	13.7
Transponder	2.0	8.0
Pulse Code Mod	2.0	19.3
GPS/SCU	2.0	12.7
GPS/DCD	2.0	11.0
Shunts	2.0	7.0
Pwr Conditioning	2.0	23.0



- Physical, Technological and cost parameters are calibrated and normalized

Cost Model Calibration



- Cost model calibrated to changes in methods and processes

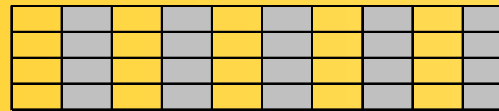
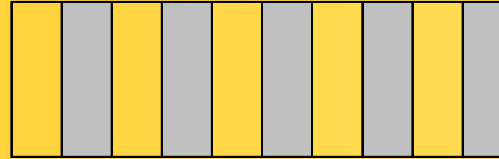
Program Characterization

05/24/01

% NEW DESIGN

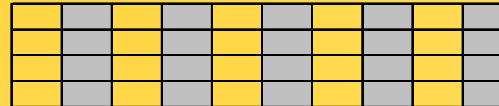
MECHANICAL & STRUCT DESIGN

30%	30%	Preliminary Design
		Stress, Dynamics analysis
10%	40%	Layout
30%	70%	Detail Drawing Follow-on
15%	85%	Assembly Drawing Follow-on
<u>15%</u>	100%	Checking & Sign-off
100%	cum	



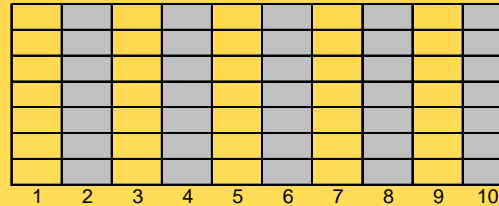
PACKAGING DESIGN

20%	20%	Layout
50%	70%	Detail Drawing Follow-on
15%	85%	Assembly Drawing Follow-on
<u>15%</u>	100%	Checking & Sign-off
100%	cum	



ELECTRONIC DESIGN

10%	10%	Block Diagram
10%	20%	Partitioning (CCA)
30%	50%	Circuit Design/Schematic
5%	55%	Part Selection,WCS*
15%	70%	Breadboard Const/Tested
15%	85%	Gen Elect Dwgs,Sign-off
<u>15%</u>	100%	Proto-Follow,Qual Test
100%		



1 2 3 4 5 6 7 8 9 10

Subsystem:

Engineer:

Extension:

Date:

* Worst Case Studies



- Scope of design work is reflected

Program Characterization

ECMPLX Engineering Complexity

	SCOPE of DESIGN EFFORT: New design different from established product line; existing technology/materials.	Value
	Personnel with extensive experience with similar designs. Many are experts in the field. Top talent leading the effort.	1.000
	Normal experience, have completed similar type designs.	1.200
	Mixed experience, some are familiar with type of design while others are new to the job.	1.400
	Unfamiliar with design, many are new to the job.	1.600

◀ ▶ \ Simple Mod / Extensive Mod / New Design / **New Product** / New Technology / Advance State Of Art /

  Parameter Value

- Scope of design work is reflected

Program Characterization

Difficulty	Interface	Tuning Alignment Adjustments	Physical Connections	INTEGX	
OPTICAL INTEGRATION					
Simple	Easy Installation	None	Set screw mounting in cell or frame	0.30	3/W
Routine	Mechanical adjustment required	Simple	Potting in cell, retainers, spacers	0.60	3/W
Moderate	Multiple optical components	Moderate	Focal length setting, check after cure	0.80	3/W
Difficult	Shimming, adjusting	Optical	Significant testing	1.00	3/W
Complex	Sophisticated test equip required	<30 arc sec	Extensive testing	2.00	3/W
Major Test Req	Ex., interferograms under thermal vac	Major	Major testing requirements	4.00	3/W
SYSTEM TESTING					
Environmental Test		Special Test Requirements			
	Thermal Vac (basic 3 plateaus)	1.50	Corona test	0.05	2
	Per additional thermal Vac test step	0.40	Live test (per 24 hrs)	0.01	2
	Vibration test	1.00	Burn-in (per 24 hours)	0.01	2
	Hot' Vib test	1.50	EMC test	1.50	2
	Mandatory Inspection Point (MIP)	0.10			2
Accessibility					
	Open Movement Field		Tight installation volume		W
	Door access, easy installation		Installation very difficult		W
	Adequate installation volume		Very tight volume, awkward movement field		W

1) Ref: GE PRICE Systems Manual,1988.

(a) SOA = State-Of-Art

2) PRICE User's Newsletter 7/90, ANT Nachrichtentechnik GmbH, Space Comm Systems.

(b) WR = wire wrap

3) Tom Tracy, Perkin Elmer (Hughes) approx 1985.

W) D. Webb experience under contract, SSD calibration in progress.

- Scope of hardware interaction is reflected

Program Characterization

INTEGRATION

Subcontract Engineering Support

DESIGN LEVEL INTEGRATION

Function	Typical	Program Fraction
System Design	0.10	
Functional Analyses	0.20	
Availability Search	0.05	
Make/Buy Trade-off	0.05	
Spec Detail & Control	0.35	
Request Bids & Review	0.05	
Modification Requirement	0.05	
Vendor Follow	0.05	
Witness Test	0.05	
Formal Acceptance	0.05	
DLEVE/S Value	1.00	0.00

INTEGRATION ENGINEERING COMPLEXITY

Difficulty	ECMPLX Value	Program Value
Off-the-shelf Support	0.2	
Simple Modification	0.2	
Moderate Modification	0.4	
Extensive Modification	0.6	
New Design-Established	0.9	
New Design-Difficult	1.0	
New Design-New Method	1.3	
New Design-Multi-Phase	1.9	
ECMPLX Value	-	

- Scope of contractor interaction is reflected

Ikonos-I Factory Cost Estimate

Basic Estimate				
Cost Summary		LM Totals	LM Production	LM Development
Ikonos-I Optical Sensor Calibration				
Thu May 24 2001 11:17 AM (PRICE Estimating Suite 2000 - SR5)				
System Cost Summary		Costs in (\$1000 As Spent)		
Program Cost	Development			
Engineering				
Draft	3213.2			
Design	10106.9			
System	2582.5			
Proj. Mgmt.	5720.0			
Data	106.7			
SubTotal(ENG)	21729.5			
HW/SW Int Cost	[66.0]			
Manufacturing				
Production	-			
Prototype	16351.3			
Tool Test Eq.	1895.8			
SubTotal(MFG)	18247.2			
G & A / CoM	0.0			
Fee / Profit	0.0			
Total Cost	39976.7			
Total (Thruput)	4130.0			
Total w/Thruput	44106.7			
Schedule Start	Jan 95	[38]		
First Item	Feb 98	[2]		
Finish	Apr 98	[40]		
System Weight	395.23	System WS	355.39	
System Series MTBF Hrs	2055			
System Quantity	0	Avg System Cost	0.00	

Preliminary Assessment of Ikonos-II cost

Ikonos-I versus Ikonos-II

FPU	Pan Channels	24	80
	Pan lines/sec	6500	19264
	Pan data rate (gbits/sec)	0.24	1.3
	Pan I5 Detector pitch	12 micron	8 micron
	Pan Array (I5) Pixels	14208	14,172 x 2
	Pan array Stage DTI	32	64
	Pan Ground Sample Distortion (GSD)	.82 m	.41 m
	Pan Pixel Size (microns)	12 um	8 um
	Pan resolution goal (2004)	.8 m	.5m
	MS Pixel size (microns)	48 um	32 um
	MS Ground Sample Distance (GSD)	3.2 m	1.6 m
	MS Array (I6) Pixels	3552 x 4 bands	7,200 x 4 bands
	MS I6 Detector pitch	48 um	32 micron
	MS Channels	12	32
	MS lines/sec	1650	4816
	Compression level	2.6	2.3
	Location in OTA		Changed
	Data rate Gbps	0.3	1.6
	OTA FOV	0.94	1.313
	QE Efficiency	35%	68%
	Readout Line Rate	6,500	19,264
	Clock drive electronics		change
	Horizontal drive electronics		change
	Array	dual forward/reverse	single bi/directional
	Swath Width	11km	11km
	Q	0.8	1.23
	Resolution	0.82	0.41
	MTF	0.154	0.103

Ikonos-I versus Ikonos-II

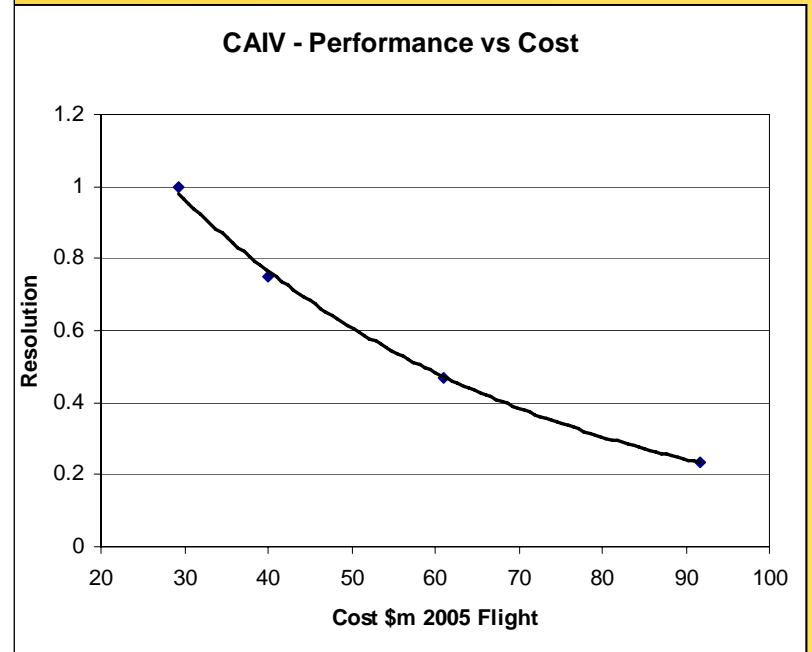
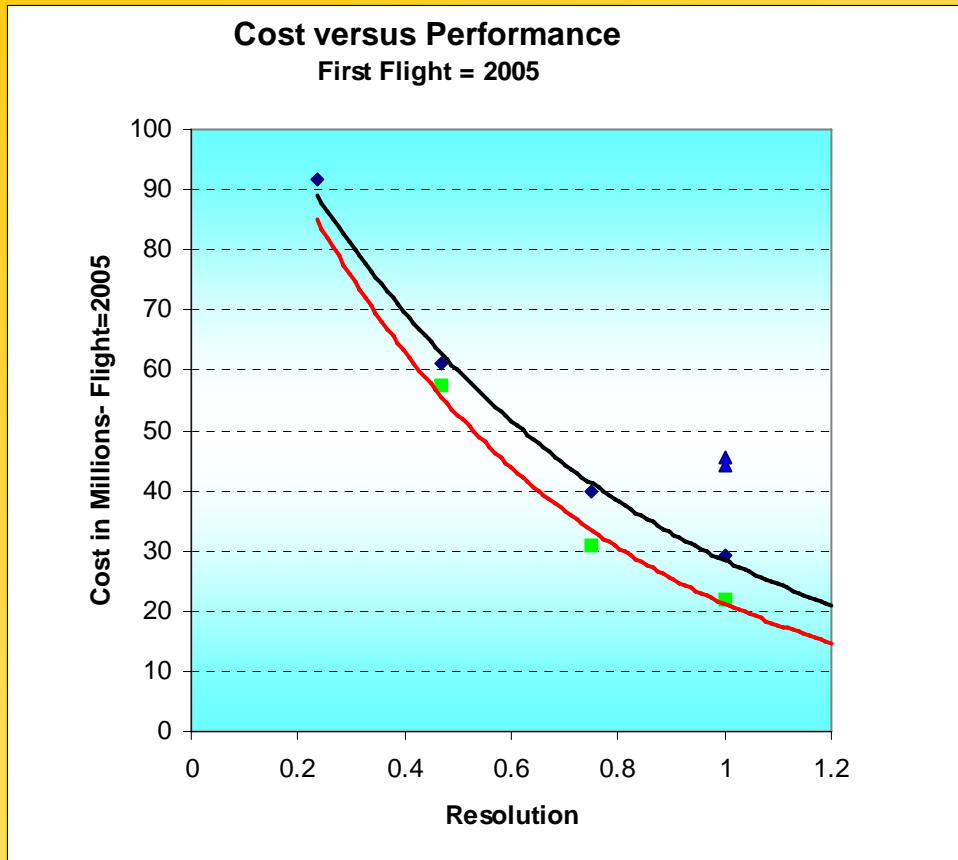
		Ikonos-1	Ikonos-2	Comments
Program	Development Start	Jan-95	Jan-02	7.0
	First Delivery	Jan-98	Feb-04	
	months	37	26	Accelerated
	Program Complete	Mar-98	Aug-04	
	months	2	5	
	Optical Sensor Units (Qty)	2	2	
	Dynamic Test Units	1	1	
	Spares	none	none	
	EDM	FPU,DPU,PSU,cables	FPU,DPU,PSU,cables	
DPU	Pan M/sec		8	
	MS M/sec		5	
Aft Enclosure			Modified	
SMA			Modified	Increased diameter
AOA	Structure		Modified	
Test Fixtures			New	
Weight			Small increase	
Power Requirements			Same	
AOA			Change	
PMA			Same	Flatter
SMA			Change	larger
TMA				Wider
FMA			Change	Add fold mirror
PMA str and AMS			New	Combined
Aft Enclosure			Modified	
Thermal			Modified	
Cleanroom		10k		
Program X				
Altitude	km	680	480	
New Facilities			New	Capitalized
Test Fixtures			New	Included
Lessons Learned				
GSE			same	

Ikonos-II

	Cost Model	
Iconos-I		44.1
Iconos-II Schedule	5.1	49.2
Tech Imp	-1.4	47.8
Recurring Only	-18.6	29.2
Improved Performance	31.9	61.1

Basic Estimate			
Cost Summary	LM Totals	LM Production	LM Development
Ikonos-I Optical Sensor Calibration			
Thu May 24 2001 12:15 PM (PRICE Estimating Suite 2000 - SR5)			
System Cost Summary		Costs in (\$1000 As Spent)	
Program Cost	Development		
Engineering			
Draft	3966.7		
Design	13770.4		
System	3806.0		
Proj. Mgmt.	6943.3		
Data	123.2		
SubTotal(ENG)	28609.7		
HW/SW Int Cost	[104.7]	
Manufacturing			
Production	-		
Prototype	24543.9		
Tool Test Eq.	3357.1		
SubTotal(MFG)	27901.0		
G & A / CoM	0.0		
Fee / Profit	0.0		
Total Cost	56510.8		
Total (Thruput)	4540.0		
Total w/Thruput	61050.8		
Schedule Start	Jan 02	[26]
First Item	Feb 04	[6]
Finish	Aug 04	[32]
System Weight	396.83	System WS	356.99
System Series MTBF Hrs	2043		
System Quantity	0	Avg System Cost	0.00

Cost versus Performance



- The essence of CAIV is the availability of available performance and cost trade space
- Cost is the requirement and performance is the output
- Optimize for best value within the trade space with customer participation