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Office for Enterprise Innovation and Sustainability

Using Modeling & Simulation to Address Supply Chain Challenges

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19 November 2009

Basic Types of Models

- **Excel Models**
- **Optimization Models**
- **Simulation Models**

Excel Model

- **Excel Spreadsheet**
- **Captures the Supply Control Study**
- **Produces**
  - **Line of Balance**
  - **Recommended Procurement & Repair**
- **Enables “What if’s”: What Are Impacts of**
  - **Different Return Rates for Overhaul**
  - **Production Lead Time**
  - **Demands**
  - **Etc.**

Optimization Models

- **Given global demand distribution and certain conditions to be met such as fill rate and customer service time, determine the optimum inventory strategy; What if demands dropped, what would then be optimum inventory? What if customer service requirements increased, what would be the optimum inventory?**
- **Given certain conditions such as the location of major customer demands and service times, determine the optimum location for distribution centers and overhaul facilities; What if a new overhaul facility was proposed such that the transportation network was altered, what is the location for the new facility to yield lowest total cost?**

Simulation Models

- **Forecast the performance of the supply chain over time;**
- **What are the future impacts of key variables such as Demand Levels and Production Lead Time;**
- **What are the impacts of shortages and delays in the lower tiers of the supply chain?**
- **What are the impacts of improved reliability?**
- **What are lifecycle costs under alternative assumptions?**

Overview of Models to be Presented

- **Excel Model**
  - **Supply Control Study**

- **Optimization Models**
  - **Optimum Inventory**
    - **Final Goods**
    - **Work in Progress**
  - **Optimum Network**

- **Simulation Models**
  - **Requirements Determination**
  - **Multi-Tier Supply Chains**
  - **Reliability Analysis and Lifecycle Costs**

Excel Model

Quick Study Objectives

- UAH obtained a copy of Quick Study from CECOM
- UAH worked with CECOM to understand functionality of Quick Study
- UAH worked with AMCOM to understand the AMCOM Supply Control Study functionality
- UAH analyzed Quick Study and made modifications and additions for application to AMCOM Supply Control process

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Quick Study Worksheet

QUICK STUDY
V 6.2
Design: 2 May 07

Date: 1-Jul-07

Material	1615-01-507-5294
Item Mgr	Item Manager Name
End Item	AH-64
FLTC:	
Nomenclature:	APACHE Tail Rotor Gearbox
FIACD:	
Acqn/Fab/SA Price:	$76,600.00
Repair Price:	$45,900.00
Fab/SA Price:	$0.00

RECOV CD:	D
FRR:	85
CON/REP IND:	R
ARIL:	E
MRP GROUP:	Z002
MRP TYPE:	PD
PROCUREMENT TYPE:	X
UNRR:	85

Final Recovery Rate

Unserviceable Return Rate

REQUIREMENTS	Time Period	QTY
PMRMO (Funded)		15
Coverage Profile Weeks	8	22
Below Dep RO (SAFT)		22
** Dependent/Other Prog Dmds		0
In-house Production Days	270	72
Planned Del Time Days	585	61
REORDER POINT		192
Lot Size Months	6	18
RQMTS OBJ		210
	Year 1	Year 2
VSF (Gross Forecast)	11.00	11.00
** Program Change Factor	1.00	1.00
Gross VSF X PCF	11.00	11.00
Net Monthly Forecast	3.05	3.05
NMCS Forecast	0.00	
Gross Avg Monthly Rtn Qty	9.35	9.35
Net Avg Monthly Rtn Qty	7.95	7.95

War Reserves
Safety Level
RLT
ALT / PLT
Procurement Cycle Requirement
Demands

O/H ASSETS	QTY
SERV ISS (Depot/Contractor)	0
SERV ISS (SSF)	7
UNSERV (On-hand, Unfunded)	8
UNSERV (Funded Project)	106
UNSERV (Funded NMC/NMP)	0
O/H OTHER (Add note below)	0
War Reserve (On-hand, Funded)	15
O/H TOTAL	136

DUE-IN	QTY
Purchase Orders (Awarded)	73
Purchase Requisition (PWD)	0
PROC TOTAL	73
Fabrication/Set Assy/Other D/I	0
GROSS TOTAL	209
Less Washout from Repair	17
LESS B/Os	0
NET TOTAL	192

** Please go to PCF & Promotions Tab if you want to make any changes to PCF, Promotions, Programmed Demands and Depot Repair requirements.

Recommendation

Supply Recommendation	Quantity	Dollars	Months To Next Proc Action
Buy	21	$1,608,600	2.00
Repair Now	8	$367,200	
# Recoverable Repair Per Month	8	$367,200	

Please refer to user guide for explanation. Monthly repair recommendation is based on what you have on-hand today or will expect back from the field.

Recommendations

Notes:

Line of Balance Worksheet

ITEM MANAGEMENT PLAN	IM:	Item Manager Name	FIACD:	0	DATE:	01-Jul-07					
	NSN:	1615-01-507-5294	RECOV:	D							
	NOMEN:	APACHE Tail Rotor Gea	ARIL:	E							
FORECAST OF DEMANDS AND RETURNS					**Jul-07**	**Aug-07**	**Sep-07**	**Oct-07**	**Nov-07**	**Dec-07**	
Gross VSF (MD63) MD04					11.00	11.00	11.00	11.00	11.00	11.00	
Program Change Factor (PCF)					1.00	1.00	1.00	1.00	1.00	1.00	
Gross VSF X PCF					11.00	11.00	11.00	11.00	11.00	11.00	
Gross Avg Monthly Returns	(Gross VSF x UNRR)		UNRR	85	9.35	9.35	9.35	9.35	9.35	9.35	
Net Avg Monthly Returns	(Gross AMR x FRR)		FRR	85	7.95	7.95	7.95	7.95	7.95	7.95	
Net VSF/Forecast	(Gross VSF - NET AMR)				3.05	3.05	3.05	3.05	3.05	3.05	
Dependent/Other Prog Dmds	Total in RO =	0			0.00	0.00	0.00	0.00	0.00	0.00	
Net Authorized Stockage Reqmt	(Net VSF/Forecast + Dep/Prog)		3.05		3.05	3.05	3.05	3.05	3.05	3.05	
				MTHS							
PMRMO (i2Log)					15	15	15	15	15	15	
SL/Coverage Profile Weeks (MD04)				2.0	22	22	22	22	22	22	
Below Depot RO (SAFT)					22	22	22	22	22	22	
Repair LT/ In-House Production Days (MD04)				9.0	72	72	72	72	72	72	
ALT/PLT Planned Delivery Days (MD04)				20.0	61	61	61	61	61	61	
PROC REO POINT					**192**	**192**	**192**	**192**	**192**	**192**	
Reo Cycle/Lot Size (MD04)				6.0	18	18	18	18	18	18	
REQMTS OBJECTIVE					**210**	**210**	**210**	**210**	**210**	**210**	
AVAIL SERV ON HAND (RRP3) - LOB					**7**	**14**	**21**	**28**	**35**	**42**	
Stock Due Out (ZSDBO/VA05)					0	0	0	0	0	0	
GFE/Other Requirements					0	0	0	0	0	0	
Due-In Repair (Funded Repair)					90	90	90	90	90	90	
Due-In Funded Purchase Order (ME2M)					73	63	53	43	33	23	
Due-In Unfunded Purchase Reqn (ME5A)					0	0	0	0	0	0	
Due-In Future Buys					0	0	21	21	21	21	
Other Due-In/Fab/ SA During RO					0	0	0	0	0	0	
Other On-Hand + Funded War Reserve					15	15	15	15	15	15	
Assets Applicable To Repair Review						8	8	8	8	8	
Recoverable Unserv On-Hand					7	7	7	7	7	7	
Assets Applicable To Proc Review					**192**	**189**	**207**	**204**	**201**	**198**	
Delivery Schedule	**Funded Repair**	CCAD	**0**								
Delivery Schedule	**Funded Repair**		**0**								
		Tot Funded Repair D/I	**0**	AWD Date							
Delivery Schedule	**Funded Proc**		**210**		**10**	**10**	**10**	**10**	**10**	**10**	
Delivery Schedule	**Funded Proc**		**0**								
Delivery Schedule	**Funded Proc**		**0**								
Delivery Schedule	**Funded Proc**		**0**								
Delivery Schedule	**Funded Proc**		**0**								
		Tot Funded Proc D/I	**210**								
Delivery Schedule	**Fab/SA/Other**		**0**								
Delivery Schedule	**Pur Reqn**		**0**								
Delivery Schedule	**Buy**		**0**								
Delivery Schedule	**Recov Unserv O/H**		**0**								
					1	2	3	4	5	6	
					Jul-07	**Aug-07**	**Sep-07**	**Oct-07**	**Nov-07**	**Dec-07**	
Supply Recommendation	**Quantity**	**Dollars**									
Buy	**21**	**$1,608,600**		Buy	0	21	0	0	0	0	
Months To Next Proc Action	**2.0**	**Months**			$0	$1,608,600	$0	$0	$0	$0	
# Recoverable Repair Per Month	**8**	**$367,200**		Repair		8	8	8	8	8	
					$0	$367,200	$367,200	$367,200	$367,200	$367,200	
					Capacity	Capacity	Capacity	Capacity	O/H OK	O/H OK	

Optimization Models

Optimization of Inventories

Objective of Logistics Support Model

- **Develop an Optimized Supply Chain model which provides recommended Sparing levels and associated costs for Line Replaceable Units to be repaired at a Special Repair Facility**

- **The model was used in support of an analysis for the U.S. Army's Light Utility Helicopter (LUH) to formulate an overall logistics strategy for a Performance Based Logistics Contract; This Was Prior to the LUH being built.**

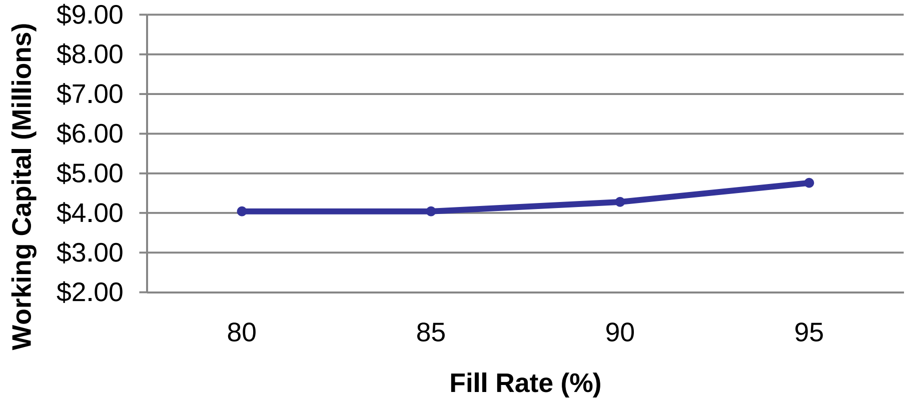
Overview of Concept

- **Assume mean demand of six parts per month;**
- **In steady state, repair completion will also need to be six per month;**
- **If repair takes six weeks (1.5 months), there will be nine WIP units in repair (1.5x6);**
- **Assume the repaired units will be sent immediately to inventory for distribution;**
- **In this case, the only inventory planned to be held is the safety stock;**
- **There is assumed to be a on-going, flow through shipment from repair to inventory to the units; and**
- **Safety stock is needed to account for variation in demand around the mean of six and, also possibly the variation in return and repair time.**

Base Assumptions

- **Assumptions**
  - **98 Units on Aircraft (96 CONUS and 2 OCONUS);**
  - **41 Flight Hours per Month;**
  - **MTBF equals 800 Hours;**
  - **Fill Rate is 85%;**
  - **Repair Time Equals 6 Weeks;**
  - **New Spare Price Equals Overhaul price, $240,000;**
  - **New Spare Production Cost Equals New Spare Price, $240,000;**
  - **Overhaul Cost is $20,000;**
  - **Shipping Time = 1 Day;**
  - **Carcasses are Readily Available for Repair when Needed;**
  - **Holding Cost = 10%;**
  - **Forecast Error is Equal to Monthly Demand.**

Sensitivity Analysis for Part Fill Rate

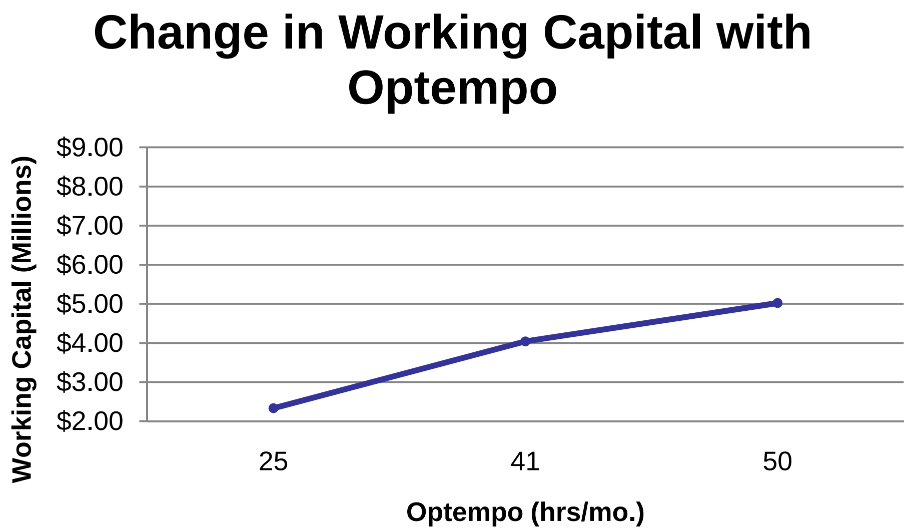


Demand	Forecast Error	Fill Rate (%)	Working Capital (M)	Safety Stock	WIP Repair
4.98	4.98	80	$4.04	9.05	7.78
4.98	4.98	85	$4.04	9.05	7.78
4.98	4.98	90	$4.28	10.05	7.78
4.98	4.98	95	$4.76	12.05	7.78

Key Assumptions for Part

FH/month	MTBF	Monthly Demand	Repair LT	Repair Cost	New Spare Cost	Holding Cost
41	800	4.98	6 weeks	$20K	$240K	10%

Sensitivity Analysis for Part Optempo



Optempo (hrs./mo.)	Working Capital (M)	Safety Stock	WIP Repair
25	$2.33	4.83	4.87
41	$4.04	9.05	7.78
50	$5.02	11.66	9.24

Key Assumptions for Part

Fill Rate	MTBF	Repair LT	Repair Cost	New Spare Cost	Holding Cost
85%	800	6 weeks	$20K	$240K	10%

Optimized WIP

Achieving Fast Response Using Optimized Work in Progress

Task

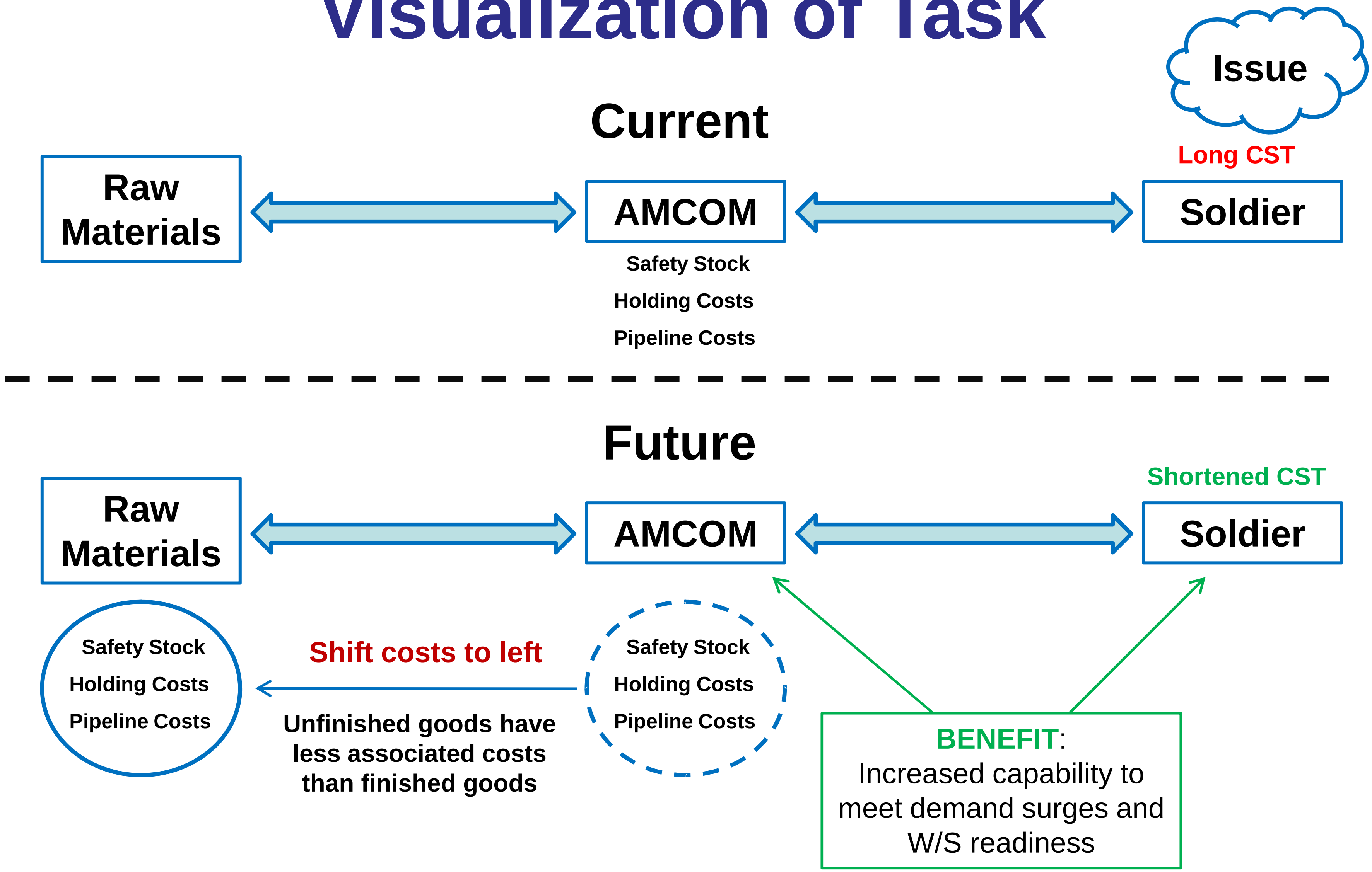
- **To Determine How to Reduce Committed Service Time (From Raw Materials to Soldier) for CH-47 Parts through Strategic Placement of WIP Inventory at OEM and Supplier Tiers**

- **To Use a Commercial Off-the-Shelf Software to Identify Potential Savings (Monetary and Time) for the Government Supply Chain; Inventory Analyst (IA) was the software used.**

Task Processes

- **Identify Critical Parts for Analysis (CH-47)**
  - **Aft Vertical Shaft**
  - **Combiner Transmission**
- **Visit and Obtain Data from Prime and Suppliers**
- **Map Supply Chain**
  - **Identify Critical Path and Critical Sub-Components**
  - **Develop Pricing and Lead-time Data for all Components**
- **Load Data and Run Inventory Analyst**
- **Analyze Results**

Visualization of Task



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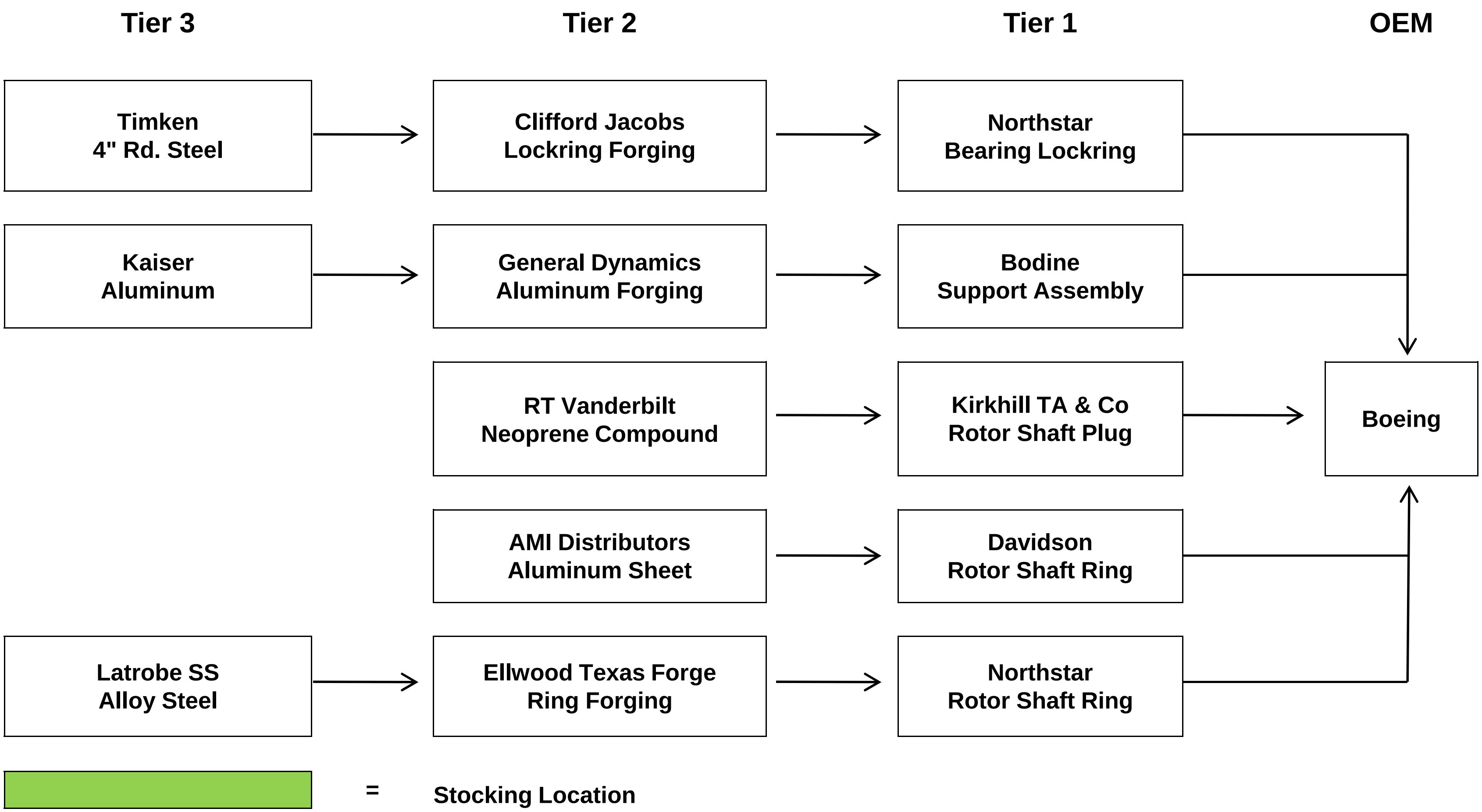
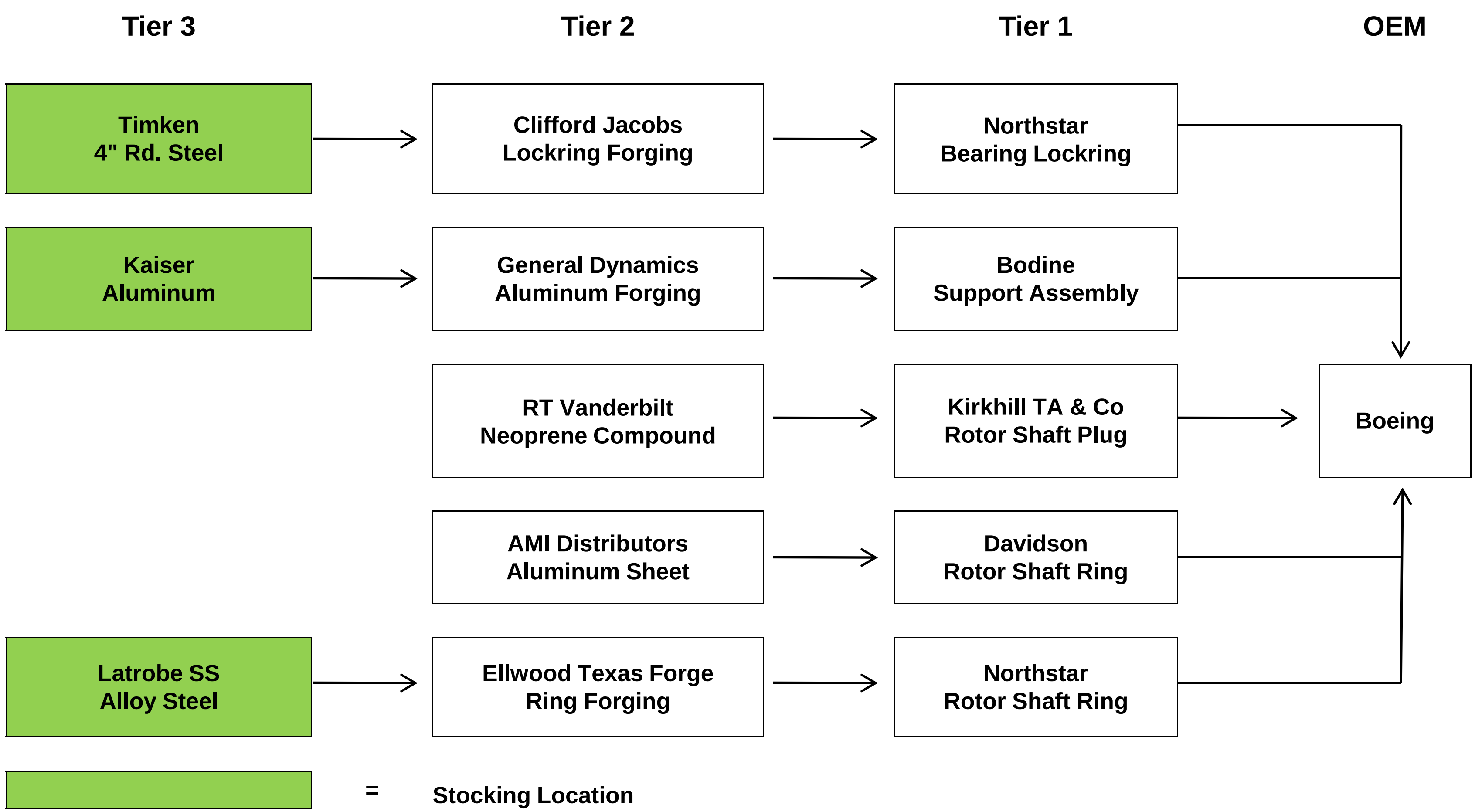
Supply Chain

Aft Vertical Shaft



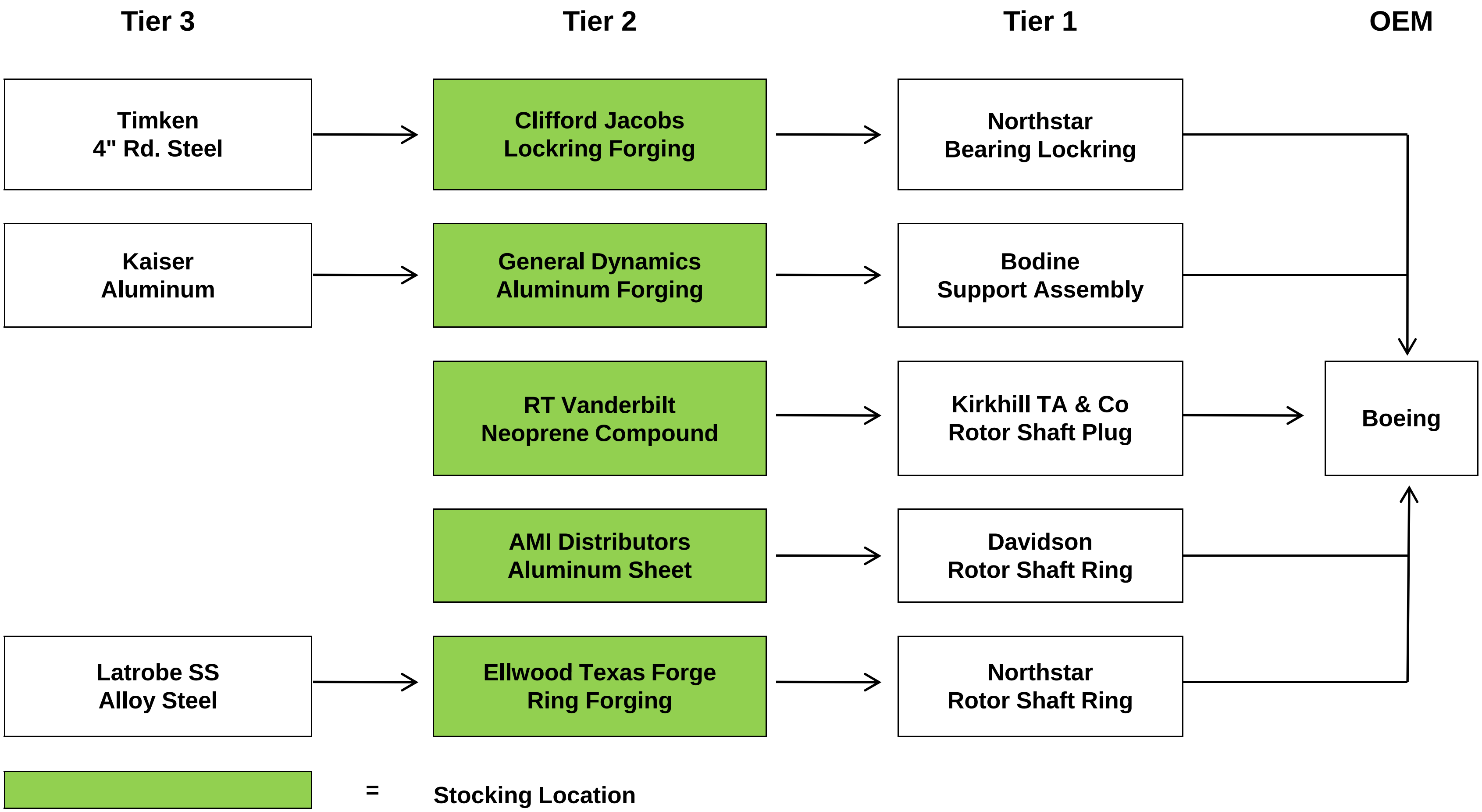
Stocking Location Tier 3

Aft Vertical Shaft



Stocking Location Tier 2

Aft Vertical Shaft



Inventory Analyst Methods 1 & 2

(50% Reduction in CST at Specified Tier)

NOTE: Manually selected stocking locations

CH-47 Aft Vertical Shaft (50% DFE)

Monthly Demands		7
New Unit Cost	$	142,000
Repair Unit Cost	$	99,400

Case	Total CST (days)	Reduction from Base Case (days)*	Working Capital (50% DFE)	WIP Investment	AMCOM One-Time Cost Savings**	AMCOM Net Holding Cost Savings***	AMCOM Total One-Time Cost Savings
Base Case	755	-	$ 9,702,871	-	-	-	-
All Stocking Locations	378	377	$ 11,807,450	$ 2,104,579	$ 12,491,267	$ 1,038,669	$ 13,529,935
Stocking Locations Tiers 3, 2, 1	483	272	$ 10,554,220	$ 851,349	$ 9,012,267	$ 816,092	$ 9,828,358
Stocking Locations Tier 1 & OEM	545	210	$ 10,970,160	$ 1,267,289	$ 6,958,000	$ 569,071	$ 7,527,071
Stocking Locations Tiers 2 & 1	559	196	$ 10,436,060	$ 733,189	$ 6,494,133	$ 576,094	$ 7,070,228
Stocking Locations Tiers 3 & 2	587	168	$ 10,015,694	$ 312,823	$ 5,566,400	$ 525,358	$ 6,091,758
Stocking Location Tier 1	650	105	$ 10,160,090	$ 457,219	$ 3,479,000	$ 302,178	$ 3,781,178
Stocking Location Tier 2	664	91	$ 9,844,535	$ 141,664	$ 3,015,133	$ 287,347	$ 3,302,480
Stocking Location Tier 3	678	77	$ 9,801,999	$ 99,128	$ 2,551,267	$ 245,214	$ 2,796,481

* Reduce all CST in indicated tiers by 50%

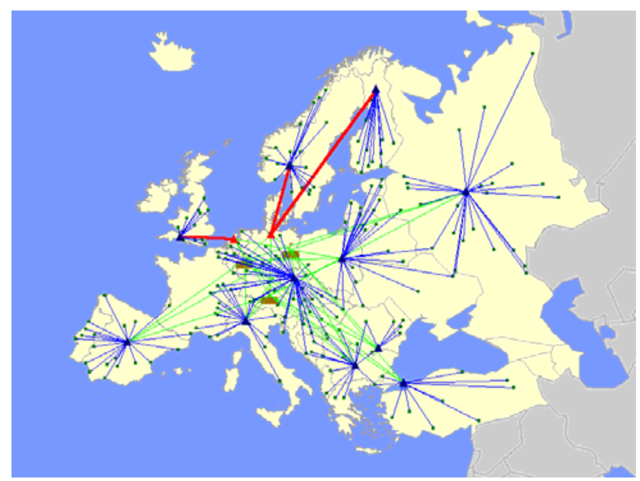
** AMCOM One-Time Cost Savings = Reduction from Base Case/30 X Monthly Demands X New Unit Cost

*** AMCOM Net Holding Cost Savings = (AMCOM One-Time Cost Savings X .10) - (WIP Investment X .10)

Optimized Network Design

Typical Questions Addressed by Network Design

- **Where should manufacturing, overhaul/repair, and distribution facilities be located?**
- **How many facilities are required?**
- **Which customers are sourced by which facilities?**
- **What are the tradeoffs between:**
  - **Inbound and outbound transportation costs; and**
  - **Fixed facility costs?**



<u>Several Factors Need to be Considered</u>

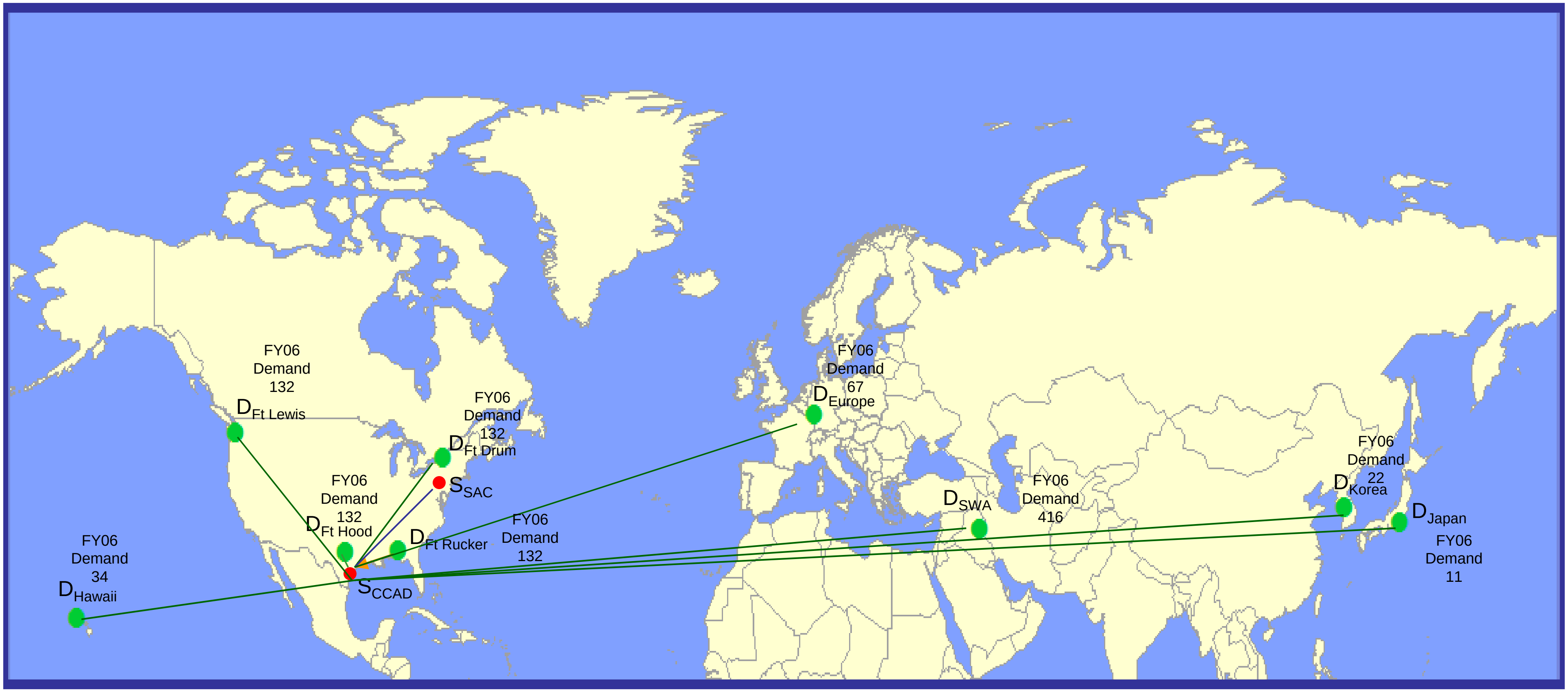
- Customer Demand, Location, Transportation
- Warehousing (inbound, outbound)
- Production Capacities and Limitations
- Cost and other constraints
  - Transportation, Distribution and Inventory costs
  - Asset limitations

LogicNet Plus®

- Off-the-shelf and ready to use
- Tight integration with Excel, Access, and SAP

Currently All Blackhawk Main Rotor Blades Flow To and From CCAD (With a Percentage Then Going to and From Sikorsky)

Supply and Demand Points



Source of Data: LOGSA & AMCOM

Summary of Results

Scenario Possible Sites with Capital Cost of New Facility	Optimization Results	% SAC	Amortized Capital Investment	Transportation Costs	In-Transit Costs	Total Annual Costs
I A. Base (CCAD Only)	CCAD	30	$0	$8,111,334	$1,380,151	$9,491,485
I B. Base (CCAD Only)	CCAD	40	$0	$8,456,080	$1,391,833	$9,847,913
II A. CCAD/Korea/Europe @$15M	CCAD	30	$0	$8,111,334	$1,380,151	$9,491,485
II B. CCAD/Korea/Europe @$25M	CCAD	30	$0	$ 8,111,334	$ 1,380,151	$ 9,491,485
II C. CCAD/Korea/Europe @$15M	CCAD	40	$0	$ 8,456,080	$ 1,391,833	$ 9,847,913
II D. CCAD/Korea/Europe @$25M	CCAD	40	$0	$ 8,456,080	$ 1,391,833	$ 9,847,913
III A. CCAD/Korea/Europe/SWA @$15M	CCAD & SWA	30	$3,000,000	$4,558,530	$678,662	$8,237,192
III B. CCAD/Korea/Europe/SWA @$25M	CCAD	30	$0	$ 8,111,334	$ 1,380,151	$ 9,491,485
III C. CCAD/Korea/Europe/SWA @$15M	CCAD & SWA	40	$3,000,000	$5,220,764	$784,117	$9,004,881
III D. CCAD/Korea/Europe/SWA @$25M	CCAD	40	$0	$ 8,456,080	$ 1,391,833	$ 9,847,913
IV A. Base (25% less SWA A/C)	CCAD	30	$0	$7,018,394	$1,145,026	$8,163,420
IV B. Base (25% less SWA A/C)	CCAD	40	$0	$7,340,432	$1,156,198	$8,496,630
V A. Base (50% less SWA A/C)	CCAD	30	$0	$6,177,835	$914,389	$7,092,224
V B. Base (50% less SWA A/C)	CCAD	40	$0	$6,561,665	$927,395	$7,489,060
VI A. CCAD/Korea/Europe/SWA (25% less SWA A/C) @$15M	CCAD	30	$0	$ 7,018,394	$ 1,145,026	$ 8,163,420
VI B. CCAD/Korea/Europe/SWA (25% less SWA A/C) @$25M	CCAD	30	$0	$ 7,018,394	$ 1,145,026	$ 8,163,420
VI C. CCAD/Korea/Europe/SWA (25% less SWA A/C) @$15M	CCAD	40	$0	$ 7,340,432	$ 1,156,198	$ 8,496,630
VI D. CCAD/Korea/Europe/SWA (25% less SWA A/C) @$25M	CCAD	40	$0	$ 7,340,432	$ 1,156,198	$ 8,496,630
VII A. CCAD/Korea/Europe/SWA (50% less SWA A/C) @$15M	CCAD	30	$0	$ 6,177,835	$ 914,389	$ 7,092,224
VII B. CCAD/Korea/Europe/SWA (50% less SWA A/C) @$25M	CCAD	30	$0	$ 6,177,835	$ 914,389	$ 7,092,224
VII C. CCAD/Korea/Europe/SWA (50% less SWA A/C) @$15M	CCAD	40	$0	$ 6,561,665	$ 927,395	$ 7,489,060
VII D. CCAD/Korea/Europe/SWA (50% less SWA A/C) @$25M	CCAD	40	$0	$ 6,561,665	$ 927,395	$ 7,489,060

Summary
(Considering Only Blackhawk Main Rotor Blades)

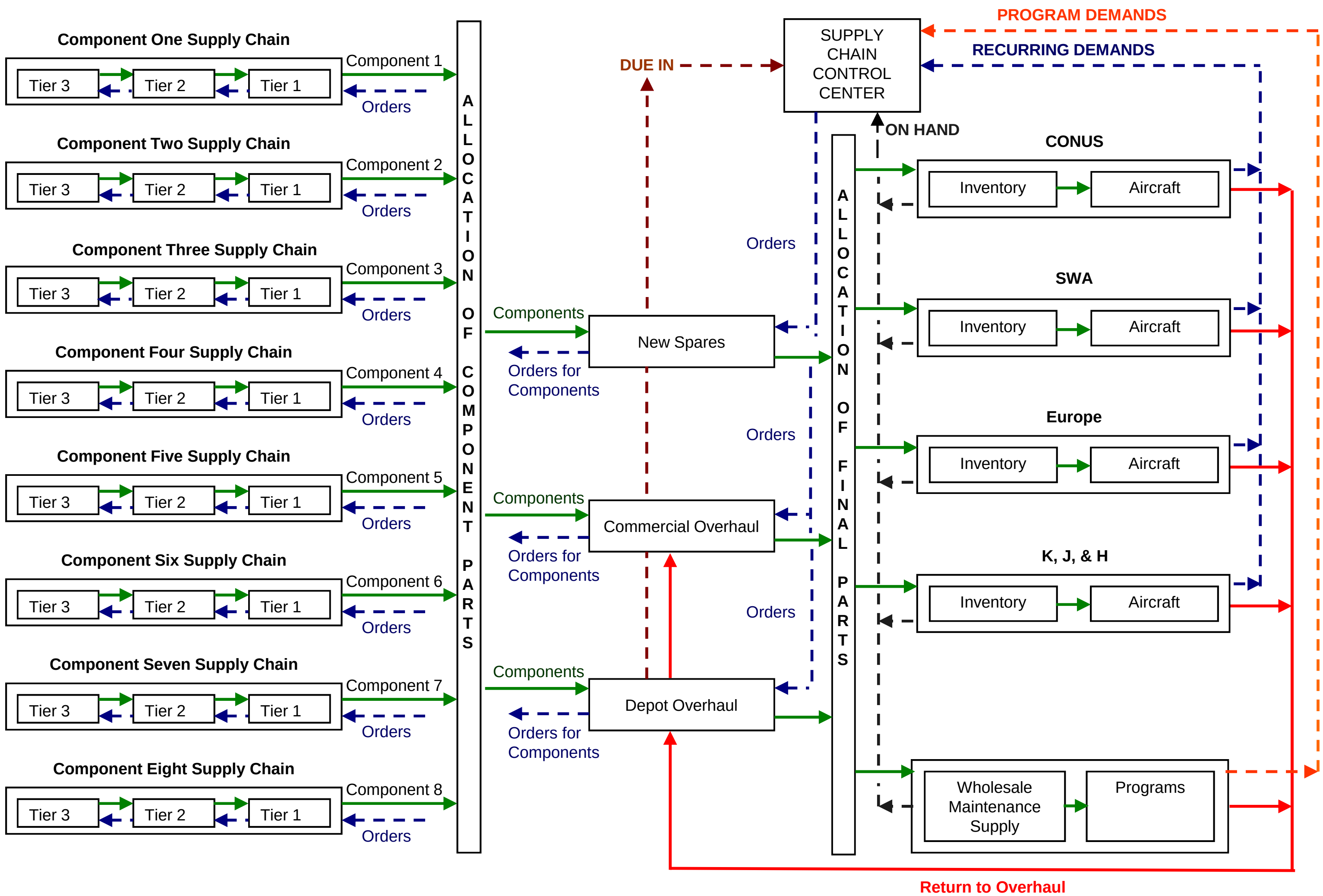
- **Given the Possibility of a Facility In Europe, Korea and SWA, the Optimization Never Puts a Repair Facility in Korea or Europe under likely demand and capital cost assumptions.**
- **Optimization does, however, locate a Repair Facility in SWA assuming current demand levels, 30% or 40% of blades going to SAC, and a capital cost of $15M for the new overhaul facility.**

- **Optimization Does Not Put a Repair Facility in SWA, But Rather Sends Everything to CCAD for the following assumptions:**
  - **With current demands and a $25M capital cost**
  - **With a 25% reduction of A/C in SWA and a $15M or $25M capital cost with either 30% or 40% of blades going to SAC**
  - **With a 50% reduction of A/C in SWA and a $15M or $25M capital cost with either 30% or 40% of blades going to SAC**
  - **With $25M capital cost**

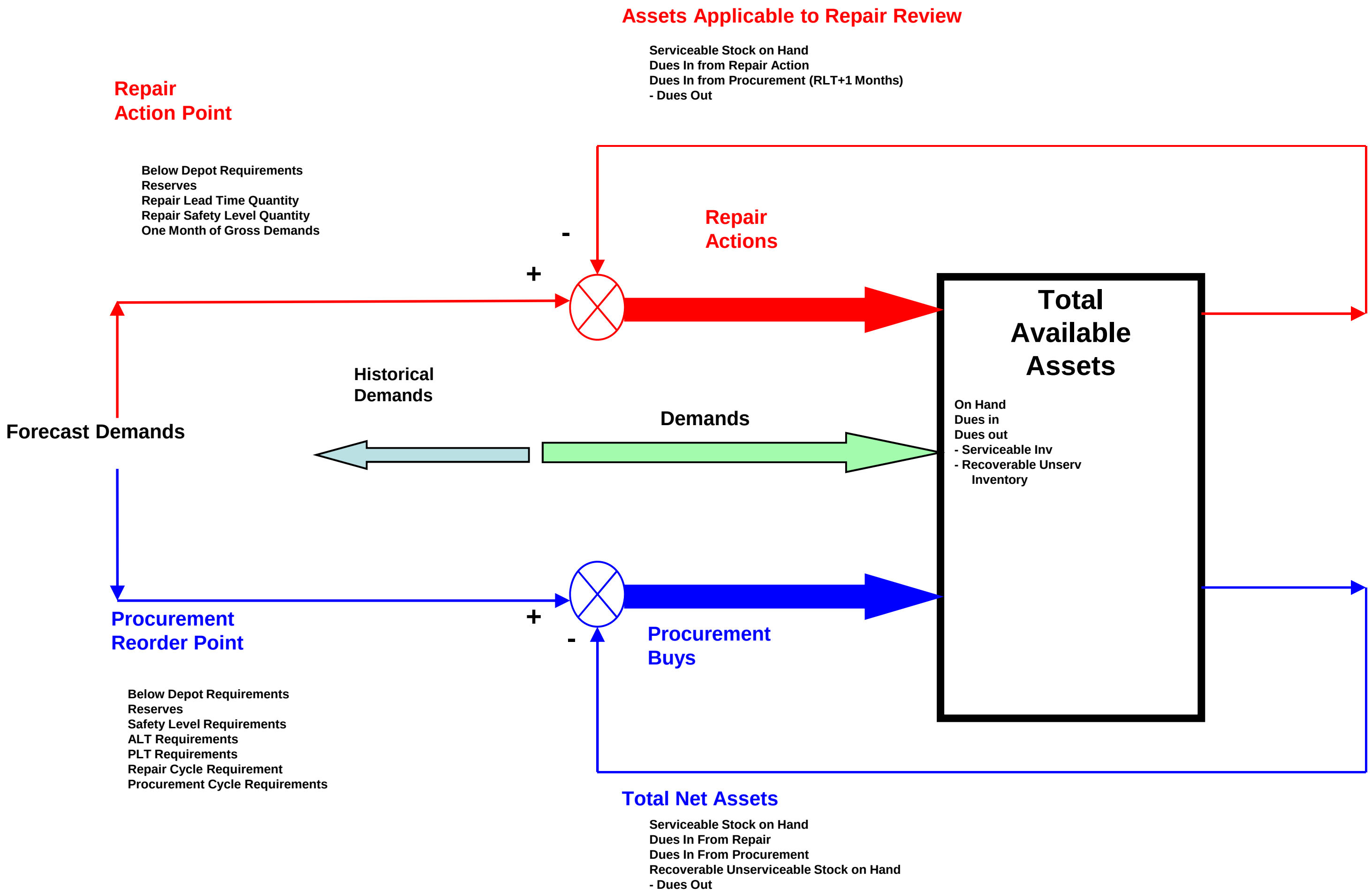
- **Analytical Capabilities Can Now be Applied to Different Assumptions and Different Parts**

Simulation Models

Overview of Enterprise Supply Chain



Feedback Structure of Supply Chain Ordering and Management System



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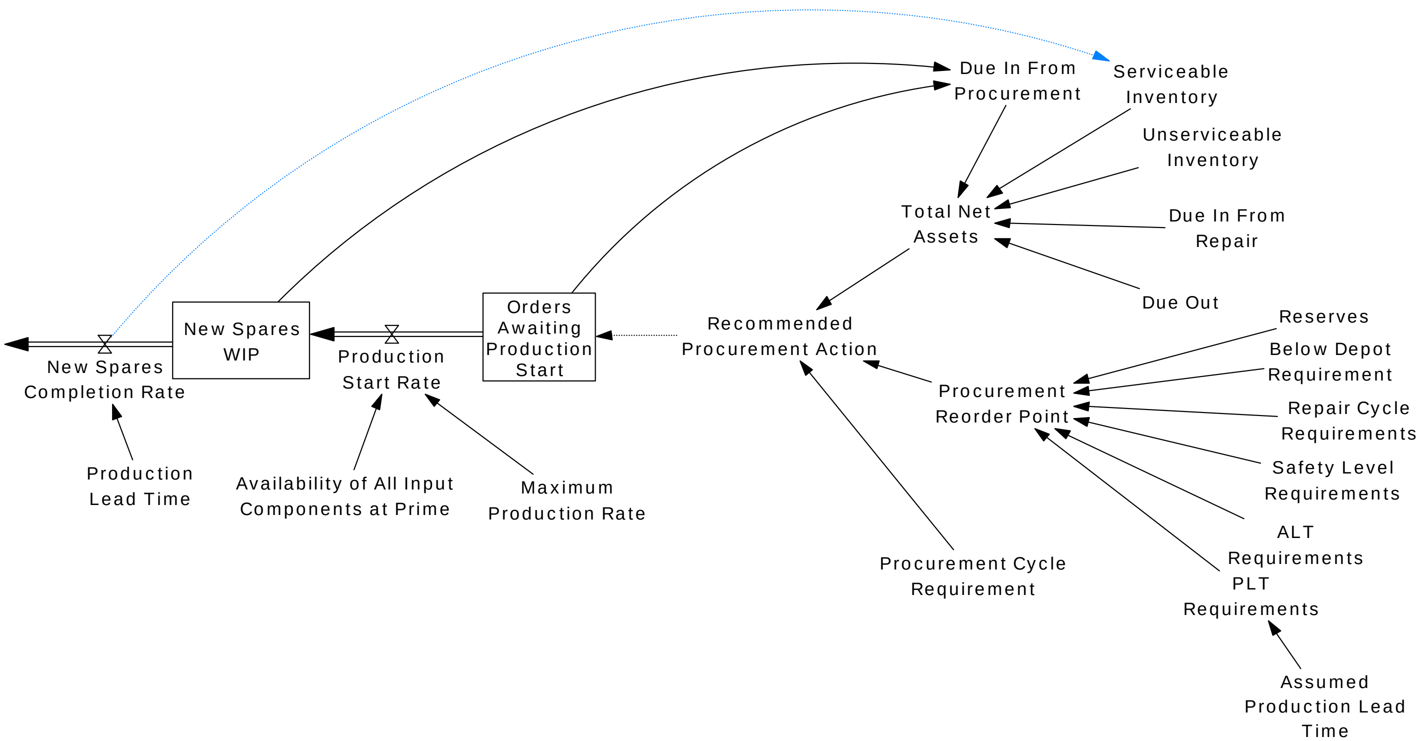
Recommended New Spares Procurement Action



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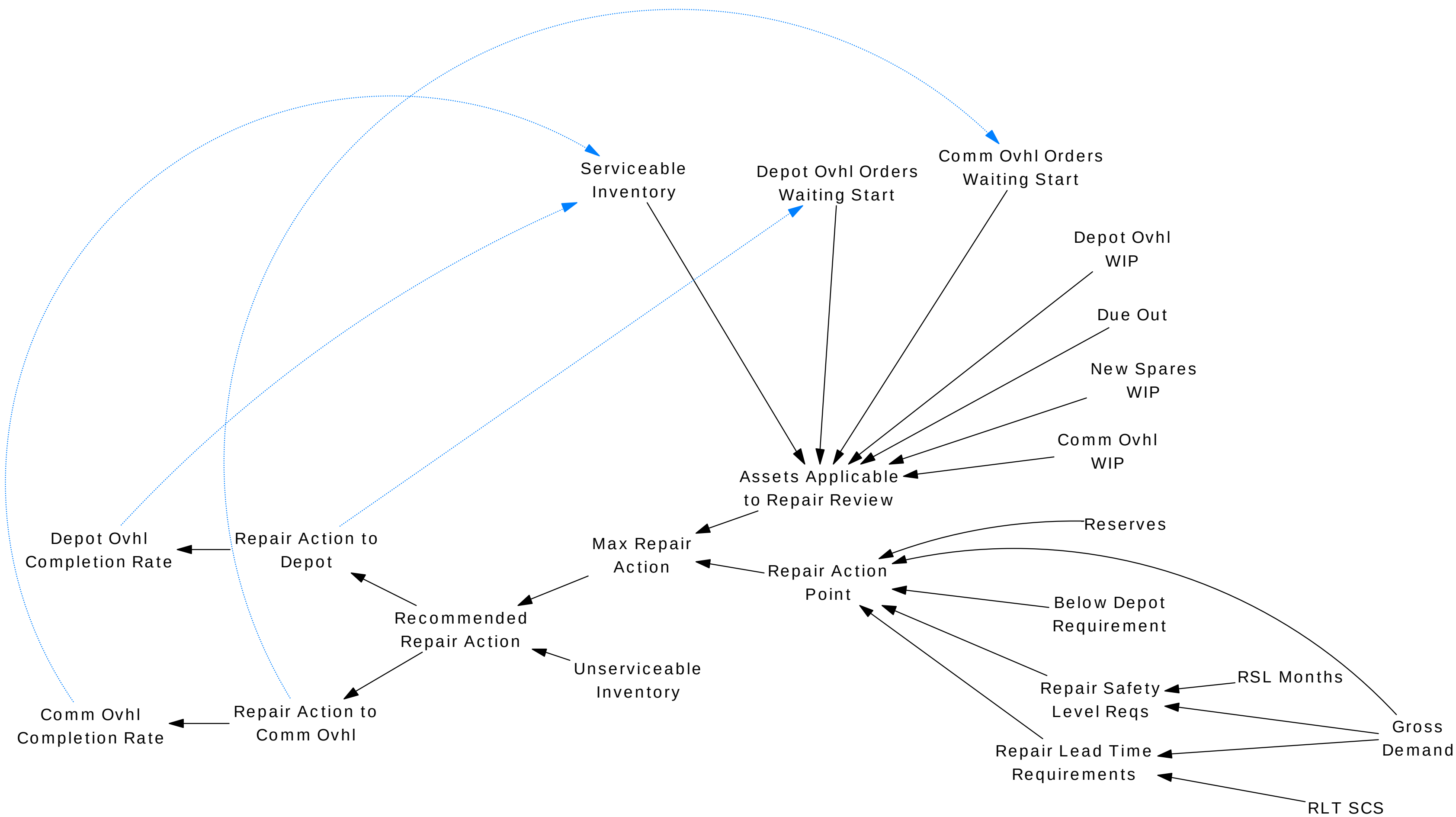
Recommended Repair Action

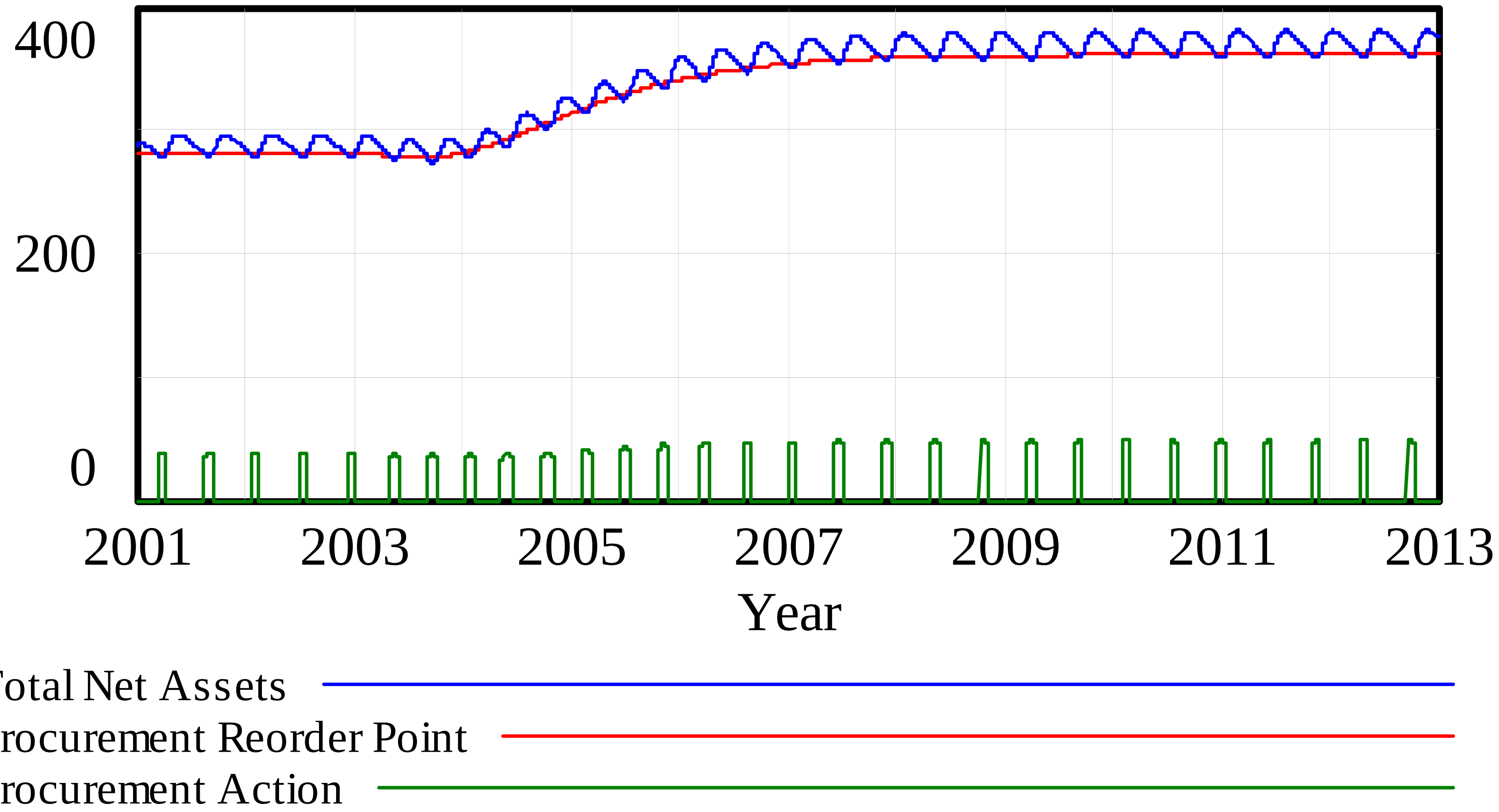


Simulation With Significant Increase in Demand in 2003

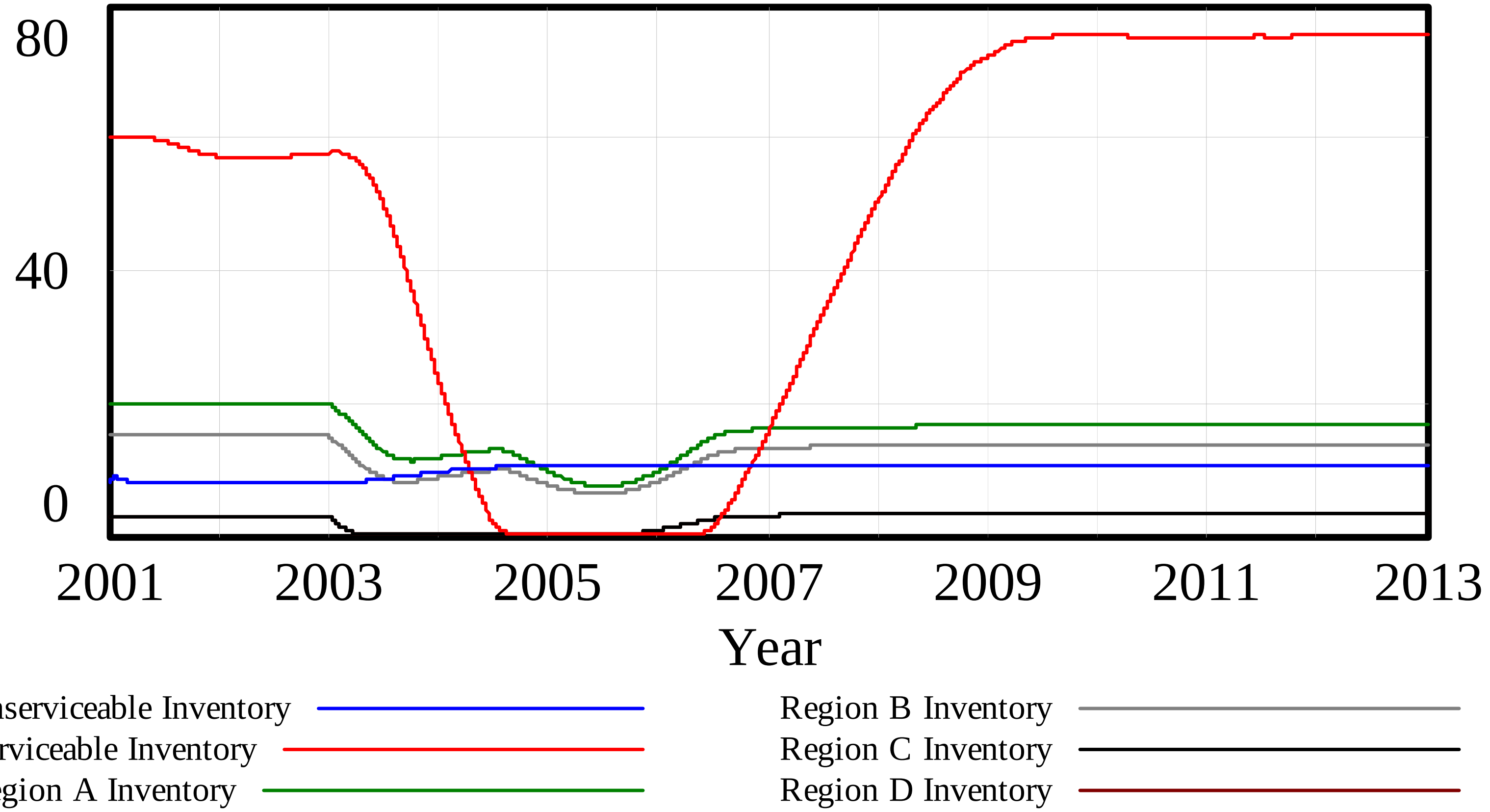
Key Assumptions:

- **Increase in Demand from 14 to 18 Parts a month in 2003**
- **No Limit on Production or Overhaul Rates**
- **Production Lead Time is 22 Months (Assumed by Army SCS Process)**
- **Overall Production Lead Time is:**
  - **-- Maximum Lead Time of Eight Component plus;**
  - **-- Production Lead Time and Administrative Lead Time of Prime Supplier**
- **Overhaul Lead Time is 11 Months (Assumed by Army SCS Process)**
- **Four Components are for New Spare Only and Have Common Lead Time of 12.2 Months**
- **Other Four Components are used for Overhaul and New Spares Production with a Common Lead Time of 8.2 Months**
- **OEM Requires 9.8 Months for Assembly and Integration for New Spares**
- **OEM Facility and Government Depot Require 2.8 Months for Overhaul Integration and Assembly**

Procurement Action w/Increase in Demand in 2003



Inventories w/Increase in Demand in 2003

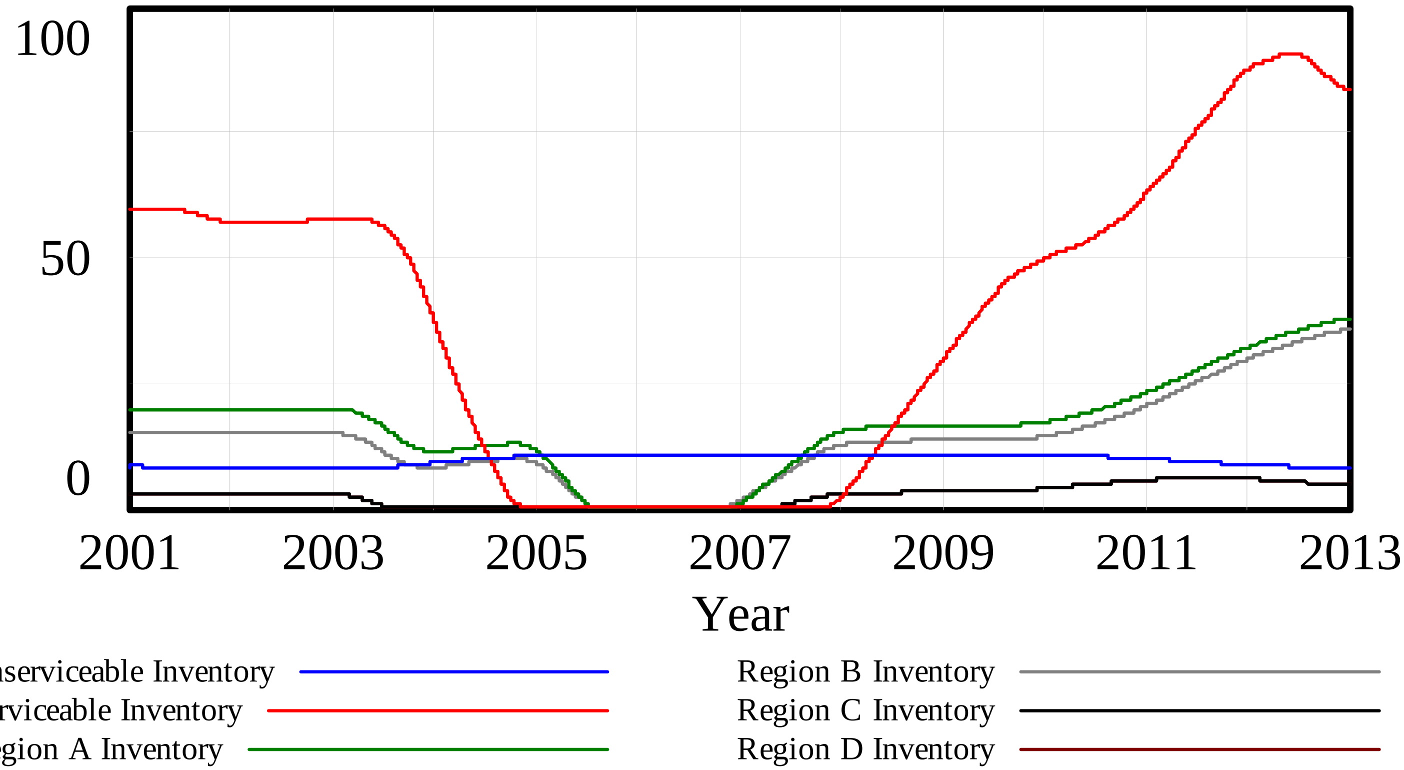


PLT Data Error

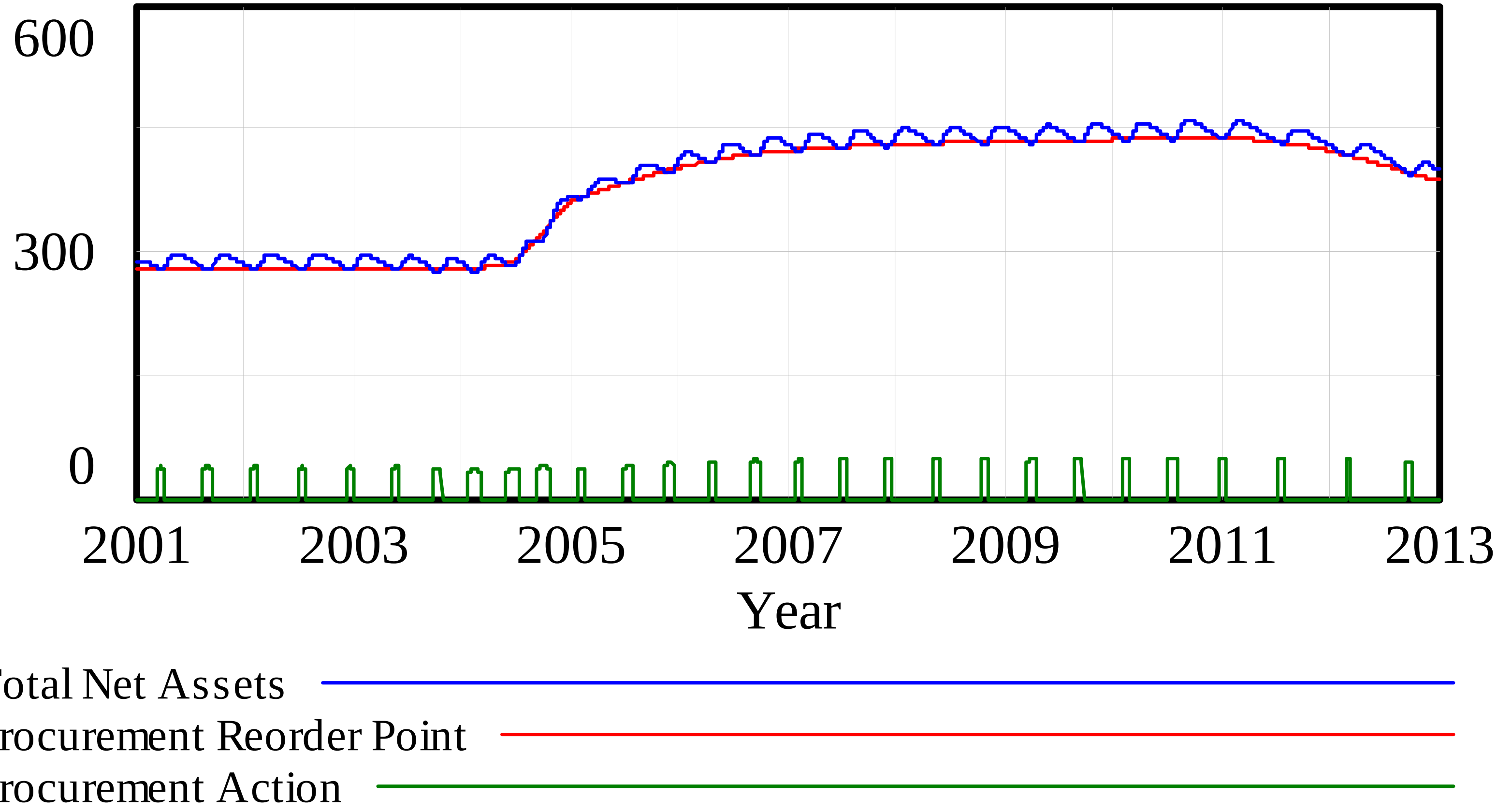
Key Assumptions:

- **Demands**
  - **-- Start out with 14 Demands per month**
  - **-- In 2003 Ramp up over six months to 18 per month**
  - **-- Start Ramping down in 2009 to 14 per month**
- **Production Lead Time is 22 Months (Assumed by Army SCS Process)**
  - **-- In 2004 Component 8 Lead Time increases by 10 months**
  - **-- Increases overall PLT to 32 months and RLT to 21 months**
  - **-- Takes One Year for Automated Process to Adjust to New Lead Times**
- **Overall Production Lead Time is:**
  - **-- Maximum Lead Time of Eight Component plus;**
  - **-- Production Lead Time and Administrative Lead Time of Prime Supplier**
- **Overhaul Lead Time is 11 Months (Assumed by Army SCS Process)**
- **Four Components are for New Spare Only and Have Common Lead Time of 12.2 Months**
- **Other Four Components are used for Overhaul and New Spares Production with a Common Lead Time of 8.2 Months**
- **OEM Requires 9.8 Months for Assembly and Integration for New Spares**
- **OEM Facility and Government Depot Require 2.8 Months for Overhaul Integration and Assembly**

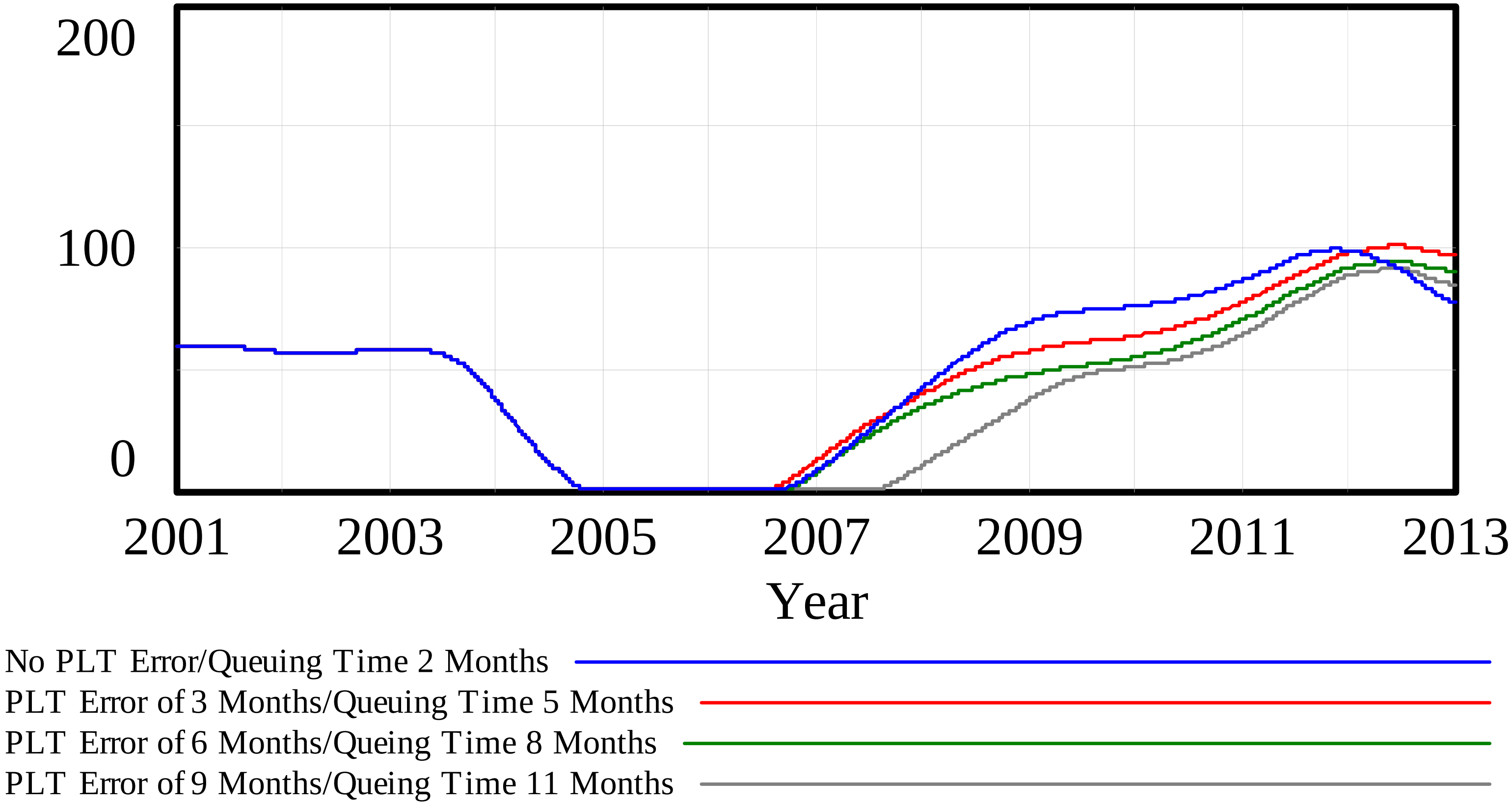
Inventories with Error in PLT



Procurement Action with Error in PLT



Serviceable Inventory with Error in PLT



Using Simulation to Determine the Likely Payoffs and Reductions in Life-Cycle Costs Arising from Investments in Improved Reliability

Objectives

- **Develop a financial model to determine for investments in reliability improvement:**
  - **Changes in supply chain performance**
  - **the breakeven point;**
  - **returns generated by savings; and**
  - **increases in available flying hours**

- **Evaluate alternative scenarios that incorporate different time frames, investment levels, improvements in reliability, and changes in unit cost; and**

- **Provide general guidelines for evaluating reliability investment strategies and impacts on life cycle costs.**

Simulation Model

- **Simulates the behavior of the AMCOM enterprise over a specified period of time;**
- **Simulates the flow of parts, information and dollars;**
- **Only a very few exogenous variables are used to drive the model over time, as examples, number of aircraft, monthly flight hours, cost of the part, reliability rates, etc.;**
- **Input variables may be changed during the time period of the simulation such as reducing the number of monthly flight hours beginning in year seven or improving reliability after a period of investment.**

Key Assumptions Driving the Model

These Variables Can Be Changed at Any Point in the Simulation for “What-If” Analyses

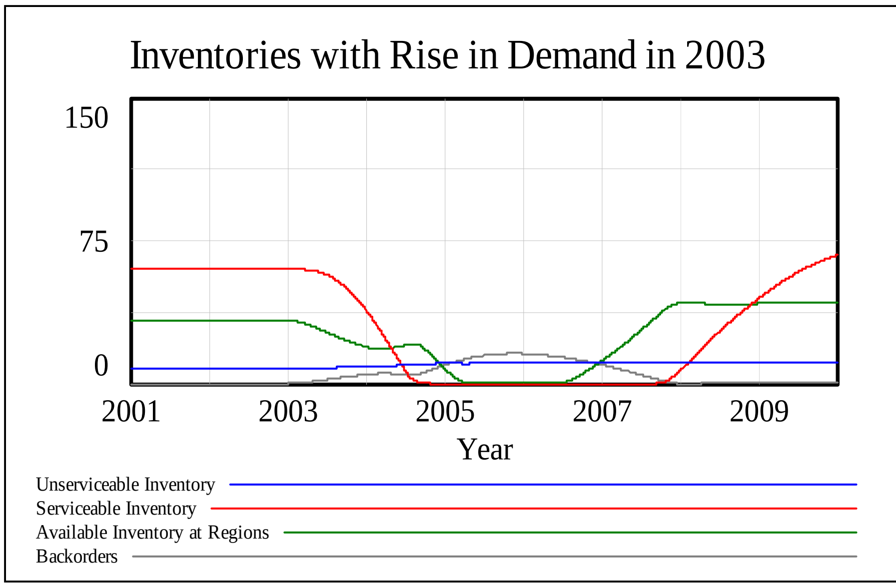
1. Flight Hours Per Month
2. Number of A/C
3. Parts per A/C
4. Failure Rate Per Flight Hour
5. New Spare Cost
6. Overhaul Cost
7. Production Lead Time
8. Overhaul Lead Time
9. Inflation Rate
10. Investment
11. Reliability Improvement & Increase in Unit Cost

Cases for Improved Reliability Over Simulation Period of 2001 - 2010

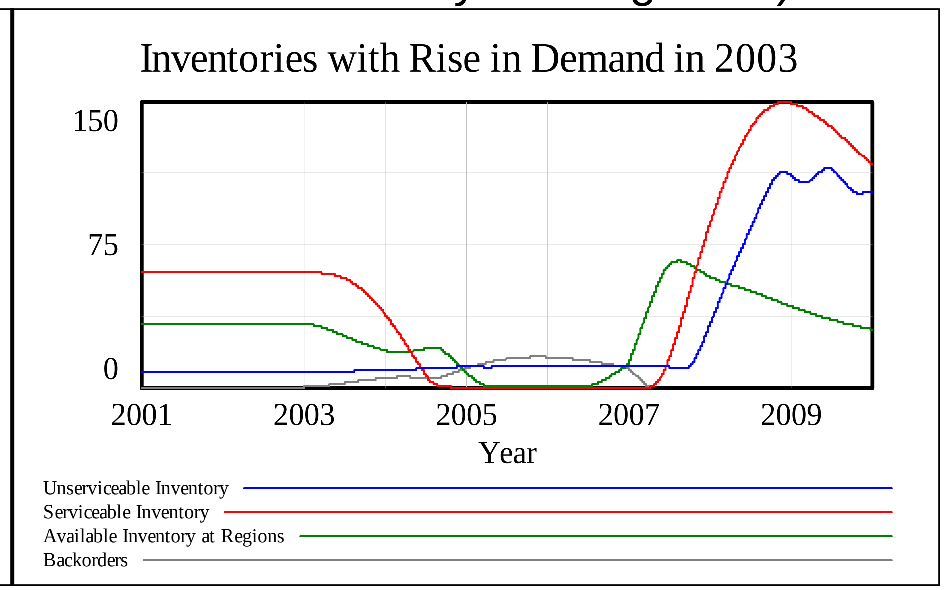
1. No Investment, No Improvement in Reliability
2. $3 Million Investment (Years 4-6), 33% Improvement in Reliability (Starting Year 7), 0% Increase in Part Cost
3. $3 Million Investment (Years 4-6), 33% Improvement in Reliability (Starting Year 7), 15% Increase in Part Cost Arising from Improved Design(Starting Year 7)
4. $3 Million Investment (Years 4-6), 50% Improvement in Reliability (Starting Year 7), 0% Increase in Part Cost
5. $3 Million Investment (Years 4-6), Rate, 50% Improvement in Reliability (Starting Year 7), 15% Increase in Part Cost Arising from Improved Design

Inventory with Reliability Improvement

Case 1



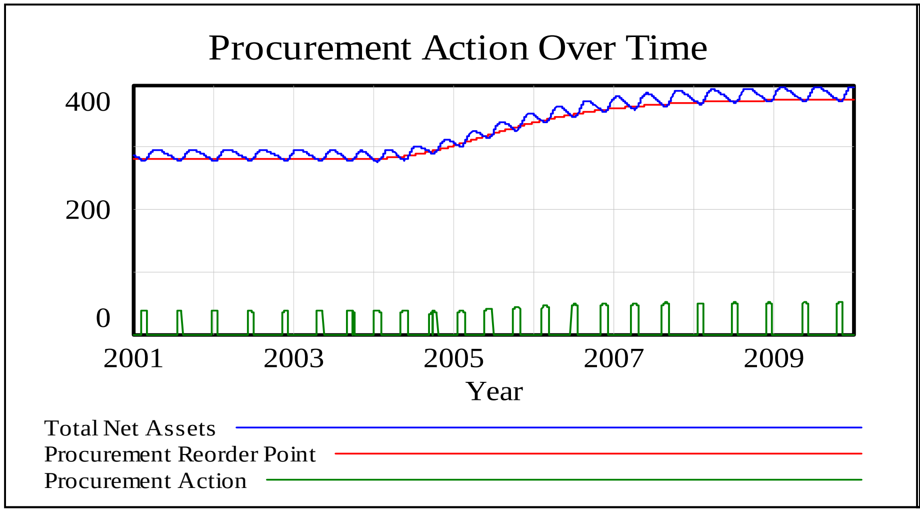
Case 4 (50% Improvement in Reliability Starting 2007)



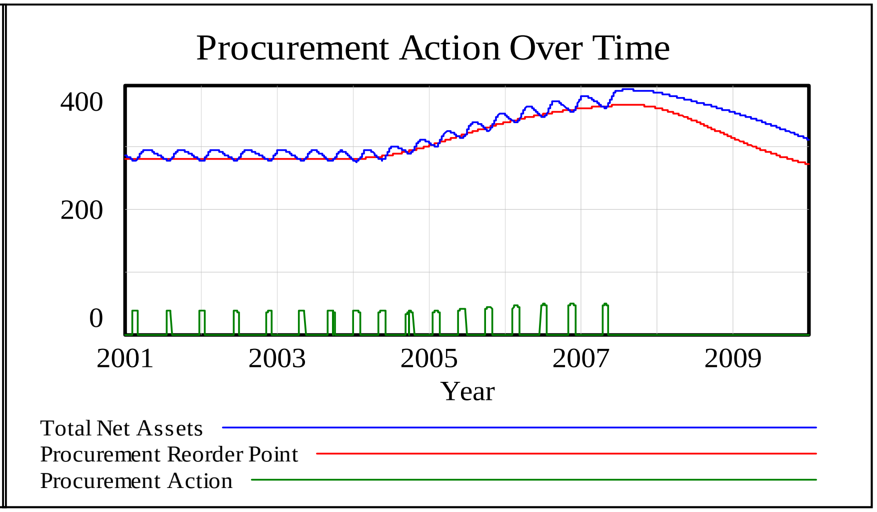
Comparative Chart 1

Procurement with Reliability Improvement

Case 1



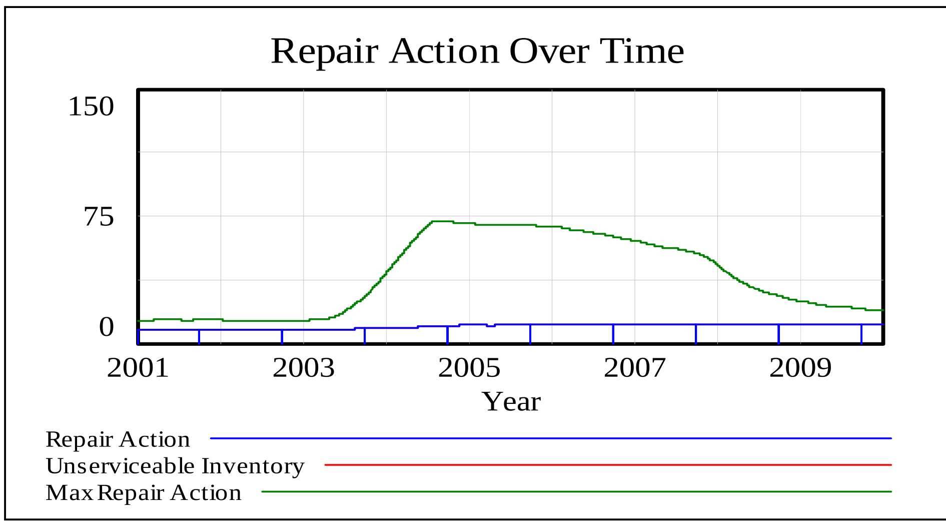
Case 4 (50% Improvement in Reliability Starting 2007)



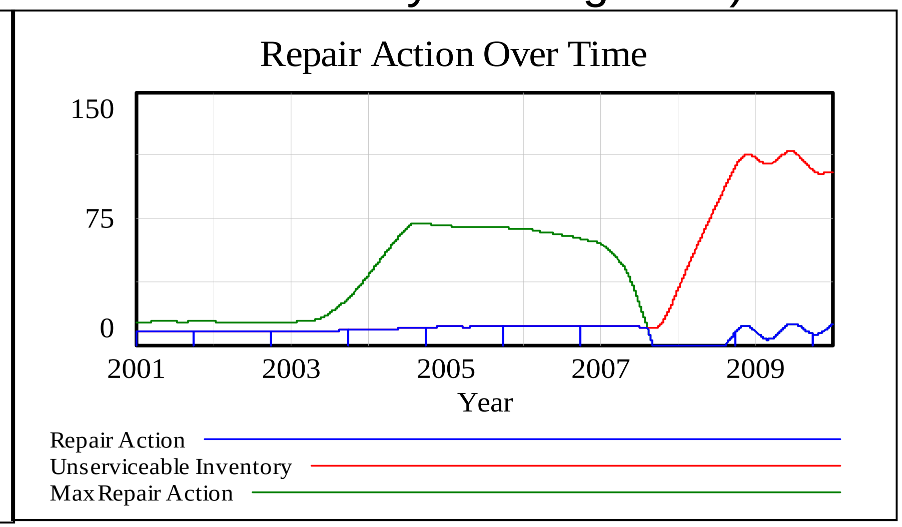
Comparative Chart 2

Repairs with Reliability Improvement

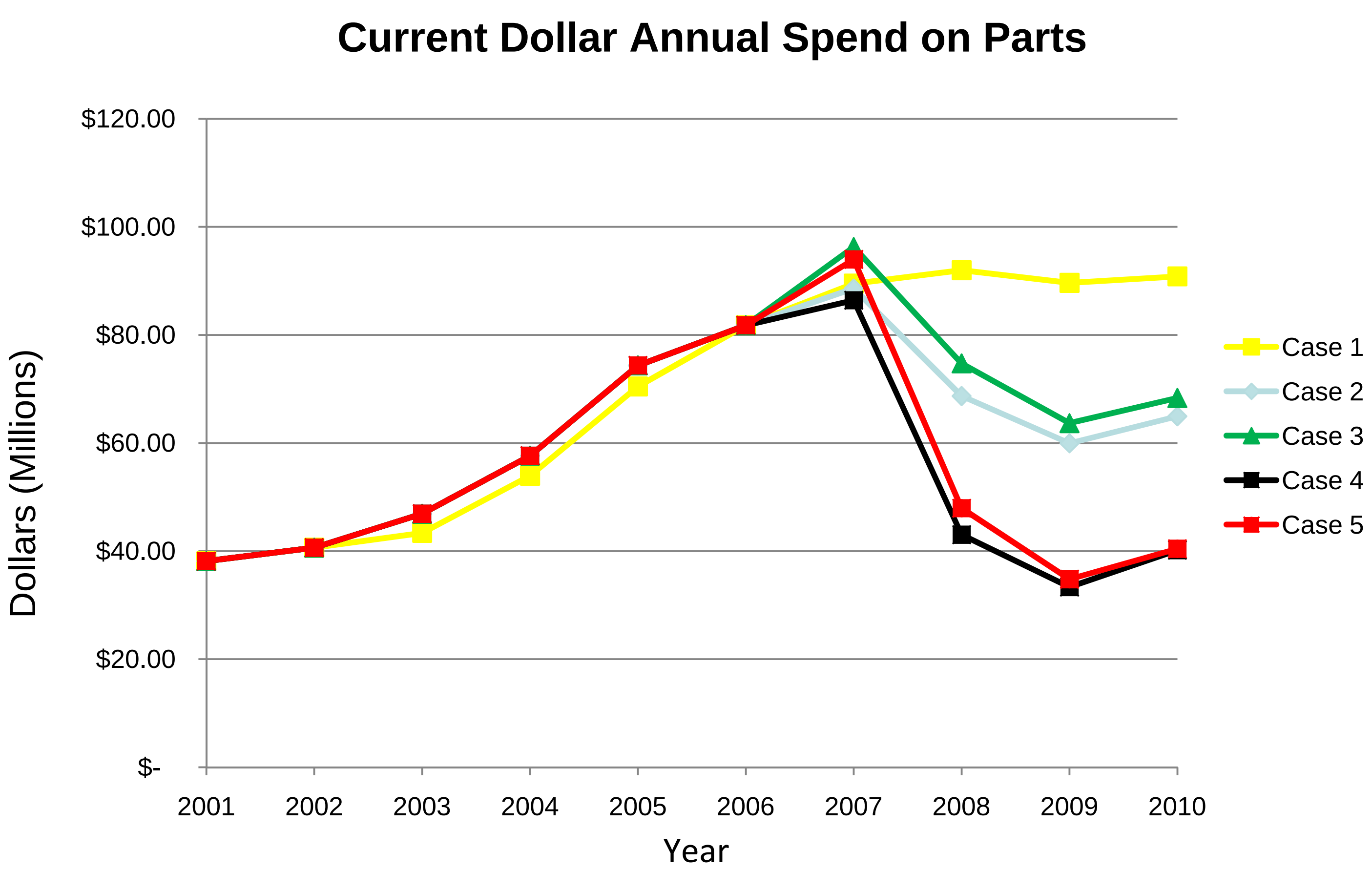
Case 1



Case 4 (50% Improvement in Reliability Starting 2007)



Comparative Chart 3



Comparative Chart 4

Financial Results

- Table 1 presents the annual spending for the five cases over the ten year period;
- Following introduction of the improved part in 2007, the table presents the annual savings arising from the improved reliability;
- It should be noted that savings for the first year are less than might be expected because parts are still being delivered after a two year production lead when orders were placed based on higher expected demands. It is for this reason that acquisition planning must be carefully integrated in order to realize full potential savings;
- The requirements determination model that is replicated in the simulation model, uses a rolling 24-month average to forecast demands; without manual intervention in requirements determination, the system will forecast a higher demand rate than required by the improved reliability; this reduces total savings;

Financial Results (continued)

- **The lower section of Table 1 presents the Time to Break Even for different levels of investment;**
- **Payback for these cases is shown to lie between One and Two years, an attractive investment.**
- **For example, these calculations show that for Case 3 with a 33% improvement in reliability and a 15% increase in part cost, a $3Million investment is recaptured in 1.56 years and a $12Million investment is recaptured in 2.06 years**

Financial Results for Reliability Improvement (Current Dollar Spending and Savings)

Current Dollar Annualized Spending

(% Improvement in Reliability, % Parts Cost Increase)

*** All Cost in Millions**

Investment Period (Months 48–72)

	Case 1	Case 2		Case 3		Case 4		Case 5	
Time (Months)	(0%,0%)	(33%,0%)	Savings	(33%,15%)	Savings	(50%,0%)	Savings	(50%,15%)	Savings
0	$ 36.00	$ 36.00	$ -	$ 36.00	$ -	$ 36.00	$ -	$ 36.00	$ -
12	$ 38.14	$ 38.14	$ -	$ 38.14	$ -	$ 38.14	$ -	$ 38.14	$ -
24	$ 40.63	$ 40.63	$ -	$ 40.63	$ -	$ 40.63	$ -	$ 40.63	$ -
36	$ 43.37	$ 43.37	$ -	$ 43.37	$ -	$ 43.37	$ -	$ 43.37	$ -
48	$ 53.93	$ 53.93	$ -	$ 53.93	$ -	$ 53.93	$ -	$ 53.93	$ -
60	$ 70.47	$ 70.47	$ -	$ 70.47	$ -	$ 70.47	$ -	$ 70.47	$ -
72	$ 81.79	$ 81.79	$ -	$ 81.79	$ -	$ 81.79	$ -	$ 81.79	$ -
84	$ 89.49	$ 88.59	$ 0.90	$ 96.26	$ (6.77)	$ 86.42	$ 3.07	$ 93.98	$ (4.49)
96	$ 91.99	$ 68.70	$ 23.29	$ 74.73	$ 17.26	$ 43.04	$ 48.95	$ 47.94	$ 44.05
108	$ 89.65	$ 59.94	$ 29.71	$ 63.67	$ 25.98	$ 33.35	$ 56.30	$ 34.79	$ 54.86
120	$ 90.84	$ 64.96	$ 25.88	$ 68.33	$ 22.51	$ 40.18	$ 50.66	$ 40.43	$ 50.41

Investment (over 3 year period: Month 37-72)					
$3 Million	B/E (years)	1.09	1.57	0.98	1.17
$6 Million	B/E (years)	1.22	1.74	1.06	1.24
$9 Million	B/E (years)	1.35	1.91	1.12	1.31
$12 Million	B/E (years)	1.48	2.06	1.18	1.37

Comparative Table 1

20 Year Life Cycle Costs Overview of Analysis

- **All of the following cases and simulations have a 20 year life cycle and simulation period;**
- **The investment in reliability improvement occurs in years 1, 2, and 3;**
- **The part with improved reliability enters service at the beginning of year 4;**
- **Several cases are examined using investment ratios and improvement ratios from the regression analysis;**
- **All cases assume the part cost (APUC) is equal to $250,000.**

Cases for Improved Reliability Over Simulation Period of 20 Years

NOTE: Investment amounts and associated reliability adjustments made in accordance with LMI regression model

6: No investment in reliability (failure rate per flight hour), no improvement

7: Investment/APUC ratio of 20 (made in Years 1-3), 60% reduction in failure rate per flight hour

8: Investment/APUC ratio of 30 (made in Years 1-3), 66.7% reduction in failure rate per flight hour

9: Investment/APUC ratio of 40 (made in Years 1-3), 69.2% reduction in failure rate per flight hour

Overview of Results

- **Chart 5 presents the dynamic behavior of inventories and shows the risk of inventory build up unless integrated planning carefully anticipated the impacts of the more reliable part;**
- **Charts 6 and 7 show that both procurement actions and repair actions slow considerably following introduction of the improved part;**
- **Chart 8 shows that constant dollar annual spending for this part drops from $36 million in the base case to $16 million for Cases 8 and 9.**

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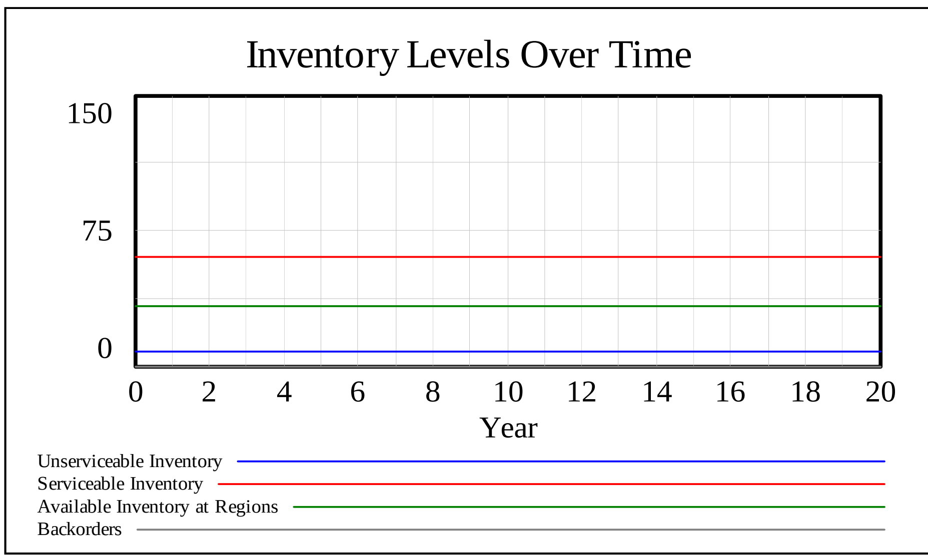
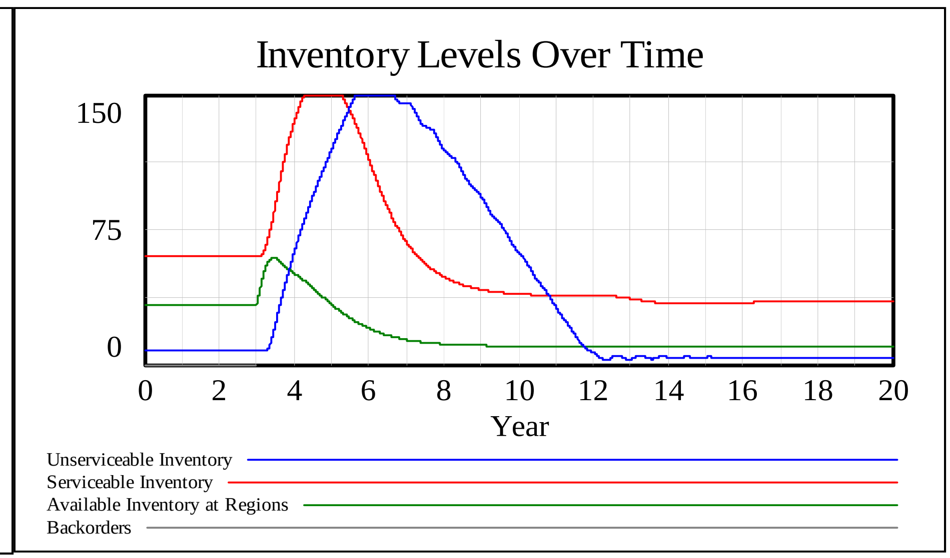
Inventory with Reliability Improvement

Case 6



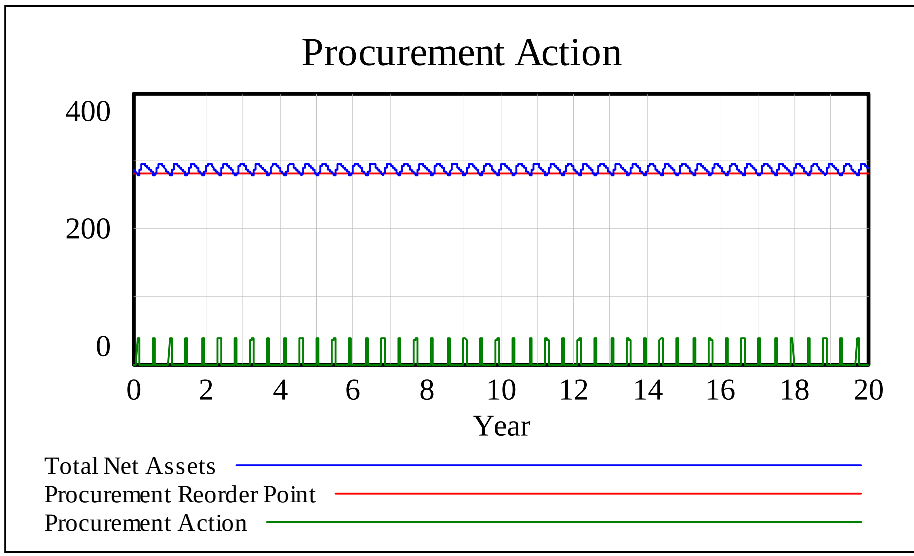
Case 9 (69.2% Improvement in Reliability Starting Year 4)



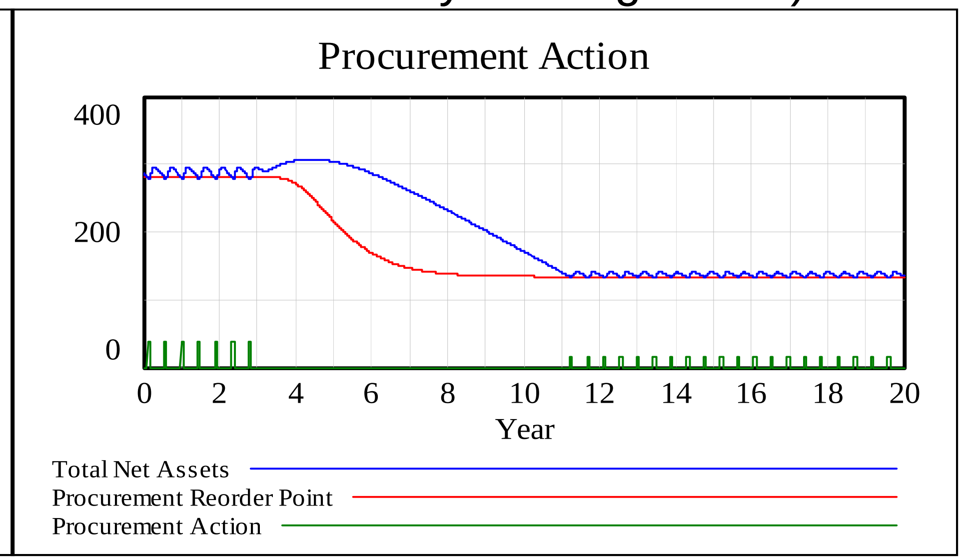
Comparative Chart 5

Procurement with Reliability Improvement

Case 6



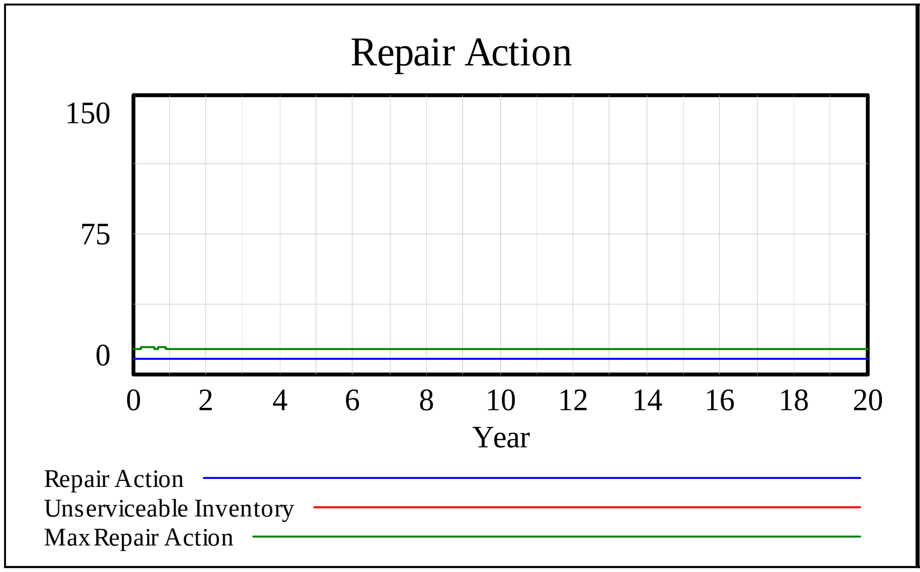
Case 9 (69.2% Improvement in Reliability Starting Year 4)



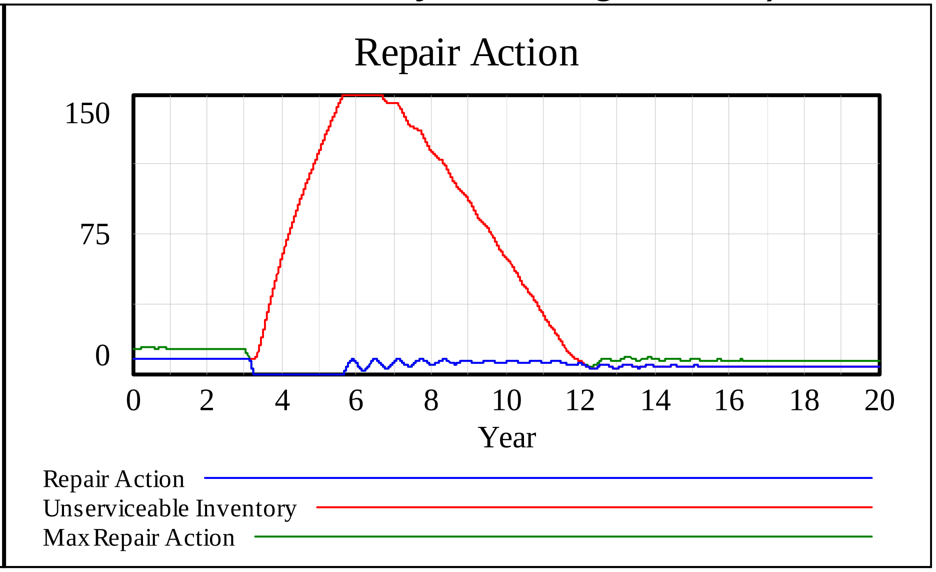
Comparative Chart 6

Repairs with Reliability Improvement

Case 6

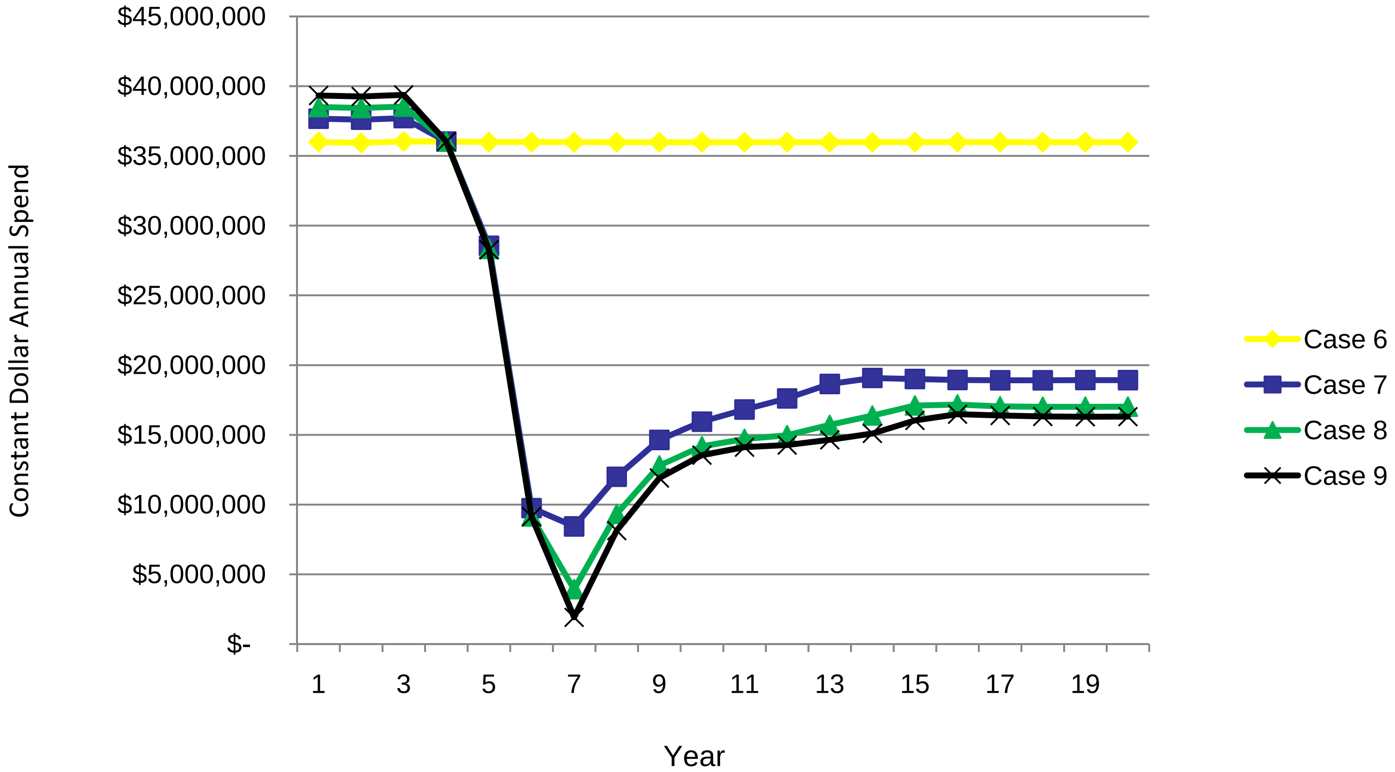


Case 9 (69.2% Improvement in Reliability Starting Year 4)



Comparative Chart 7

Comparison of Various Cases in Constant Dollar Annualized Spending



Comparative Chart 8

Investment/APUC vs. Reduction in Costs/Costs

Investments made for improved reliability can result in large cost savings over the course of the life cycle. The greater the improvement in reliability, the larger the reduction in life cycle costs.

Comparative Table 2 presents life cycle cumulative costs, savings arising from improved reliability, and the percentage of savings from the base cost for alternative cases.

Comparative Table 2 illustrates the dramatic effect reliability improvements can have on life cycle costs, especially for costly parts.

Investments in improved reliability on the order of $7.5 to $10 million generate estimated life cycle cost reductions of roughly $300 million, this may be interpreted approximately as needing to buy 1,300 fewer parts over the 20 year life cycle.

Reductions in Life Cycle Costs

Case	Investment	Investment/ APUC	Reliability Improvement %*	Cumulative Costs From Simulation (Constant $)	Savings	Savings/ Base Cost
6	$ -	0	0%	$ 683,697,000	$ -	0
7	$ 5,000,000	20	150%	$ 397,102,000	$ 286,595,000	41.92%
8	$ 7,500,000	30	200%	$ 367,032,000	$ 316,665,000	46.32%
9	$ 10,000,000	40	225%	$ 357,376,000	$ 326,321,000	47.73%

* From LMI regression equation

Comparative Table 2

Impacts of Improved Reliability on Availability/Readiness

The following Table illustrates the impacts of failure rate per flight hour reductions on aircraft availability and readiness. Failure rate reductions lowers the average monthly removals and leads to increased annual aircraft availability hours.

Impacts of Improved Reliability on Aircraft Availability/Readiness

Case	% in Failure Rate Reduction (Failure Rate per Flight Hour)	Average Monthly Demands	Unavailable Hours per Year*	Unavailable Hours Reduction %	Annual Reduction in Aircraft Impacted	Annual Additional Availability Hours
6	-	14.0	12,096	-	-	-
7	60.0%	7.4	6,394	47.1%	79	5,702
8	66.7%	6.7	5,757	52.4%	88	6,339
9	69.2%	6.4	5,519	54.4%	91	6,577

*Unavailable Hours per Year = Average Monthly Demands X 72 Hours (i.e. Unavailable Flying Hours per Removal) X 12

Summary for Simulation Models

- **A dynamic financial and supply chain simulation model successfully addresses the issues revolving around OPTEMPO, reliability and life cycle cost;**
- **Dynamics of investment, payback, and reliability are made extremely complex because of time lags and feedback;**
- **Many anticipated efficiencies may well be lost if improved reliability is not incorporated into supply planning;**
- **Payback depends strongly upon level of demand, part cost, flight hours, existing levels of reliability and magnitude of investment.**

Overall Summary & Conclusions

- **No "One Size Fits All"; the Analytic Objectives Drive the Type and Structure of Model to be Used;**
- **There Will Always be Trade-offs Between Data Requirements, Ease of Use, and Model Structure;**
- **There is Never a Single Solution; Models Should be Used to Examine the Sensitivity of a Solution to the Key Assumptions;**
- **Models are Tools to be Used in Assisting Management to Develop Decisions and Recommendations.**