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Potential Cost Savings with 3D Printing Combined With 3D Imaging and CPLM for Fleet Maintenance and Revitalization

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An IT Adoption Challenge

- Cost constrained DoD environment requires cost reduction
- Threats require US military to retain technological superiority
- Complex IT acquisition process
- **Improved ship maintenance and revitalization has potential for successfully addressing these needs**
  - SHIPMAIN-recommended new technologies
    - 3D Laser Scanning Technology (3D LST)
    - Collaborative Product Lifecycle Management
  - Additive Manufacturing (3D printing)

Research Context

<u>Problem</u>: Learning curve savings forecasted in SHIPMAIN maintenance initiative have not materialized. ***Why?***

<u>Hypothesis</u>: The right mix of new technologies have not been adopted and widely used.

This research tests the impacts of technology adoption strategies on Navy maintenance cost savings.

Potential Technology:
3D Terrestrial Laser Scanning

- Laser scans space from highly articulated mount, often combined with 360^{o} camera
- Software processes points into 3D image of the space. Processed into CADD format.
- Currently used in automotive, offshore construction and repair, civil and transportation, building construction, fossil fuel and nuclear power plants
- Recommended as part of SHIPMAIN
- **Potential Navy uses:** map spaces for ship retrofit & upgrades, existing conditions surveys as part of damage assessment, fitting requirements for repairs

Potential Technology:

Collaborative Product Lifecycle Management (CPLM)

- To "integrate people, processes, and information"
- Electronically integrates design documents, data bases, 3D LST, etc., for participant collaboration across physical distances and time.
- Common, shared sets of documents improves access, collaboration, coordination, communication
- Common platform for program change management
- Recommended as part of SHIPMAIN
- **Potential Navy uses:** configuration control, parts design libraries, cross-vessel and cross-platform coordination of revitalization

Potential Technology:
Additive Manufacturing
("3D Printing")

- 3D design/image of final part. Create net.
- Geometric slicing of image into horizontal layers for manufacturing
- Incrementally add small amounts of material in very thin layers of material to build-up part
- Variety of possible materials (plastic, titanium) & methods (e.g. for material bonding)
- No dominant method, materials, suppliers
- Developed since SHIPMAIN recommendations
- **Potential Navy uses:** fast parts manufacturing for repair, less expensive creation of few parts, improved designs (e.g. less weight)

Research Approach

1. Collect data on Navy use of Additive Manufacturing.
2. Build simulation model (system dynamics) of Naval parts manufacturing for ship maintenance.
3. Simulate steady-state technology adoption and use strategies.
4. Build Knowledge-Value-Added models of technology adoption and use strategies. Use simulated strategies to simulate Returns-on-Investment (ROI).
5. Use Returns-on-Investment to estimate costs and thereby cost savings of technology adoption and use strategies.

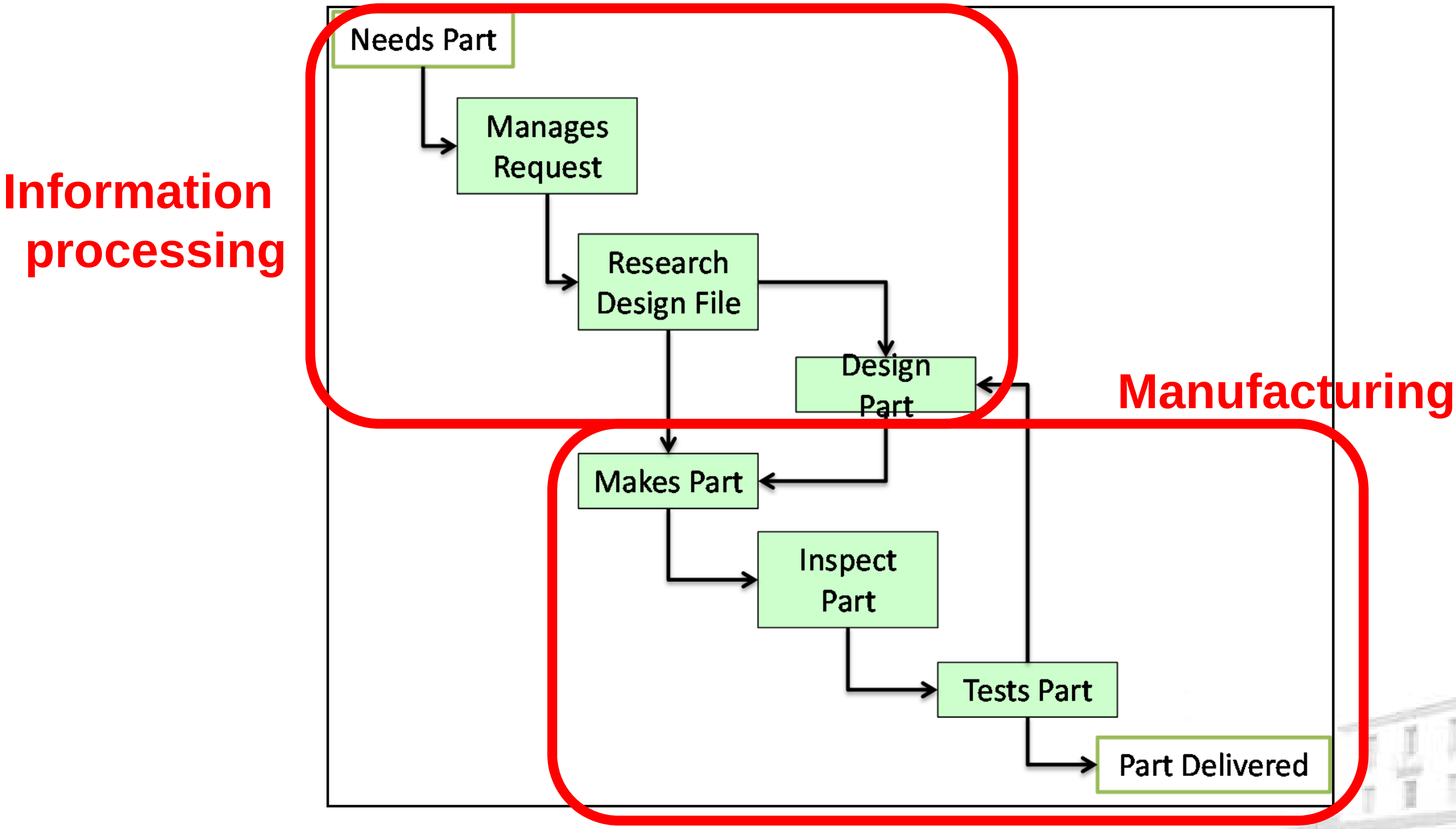
1) Data Collection

- Naval Surface Warfare Center Port Hueneme Division (NSWC PHD), May 10, 2013 - use of AM by that facility.
- Fleet Readiness Center Southwest, Naval Air maintenance Depot, San Diego July 17-18, 2013 – use of AM at North Island NAVAIR maintenance depot.

- **Description and estimates for modeling.**
  Ex: *Repair parts process,* Manufacturing process, manpower requirements, Avg. value of parts ($), manufacturing rates

1) Data Collection Results

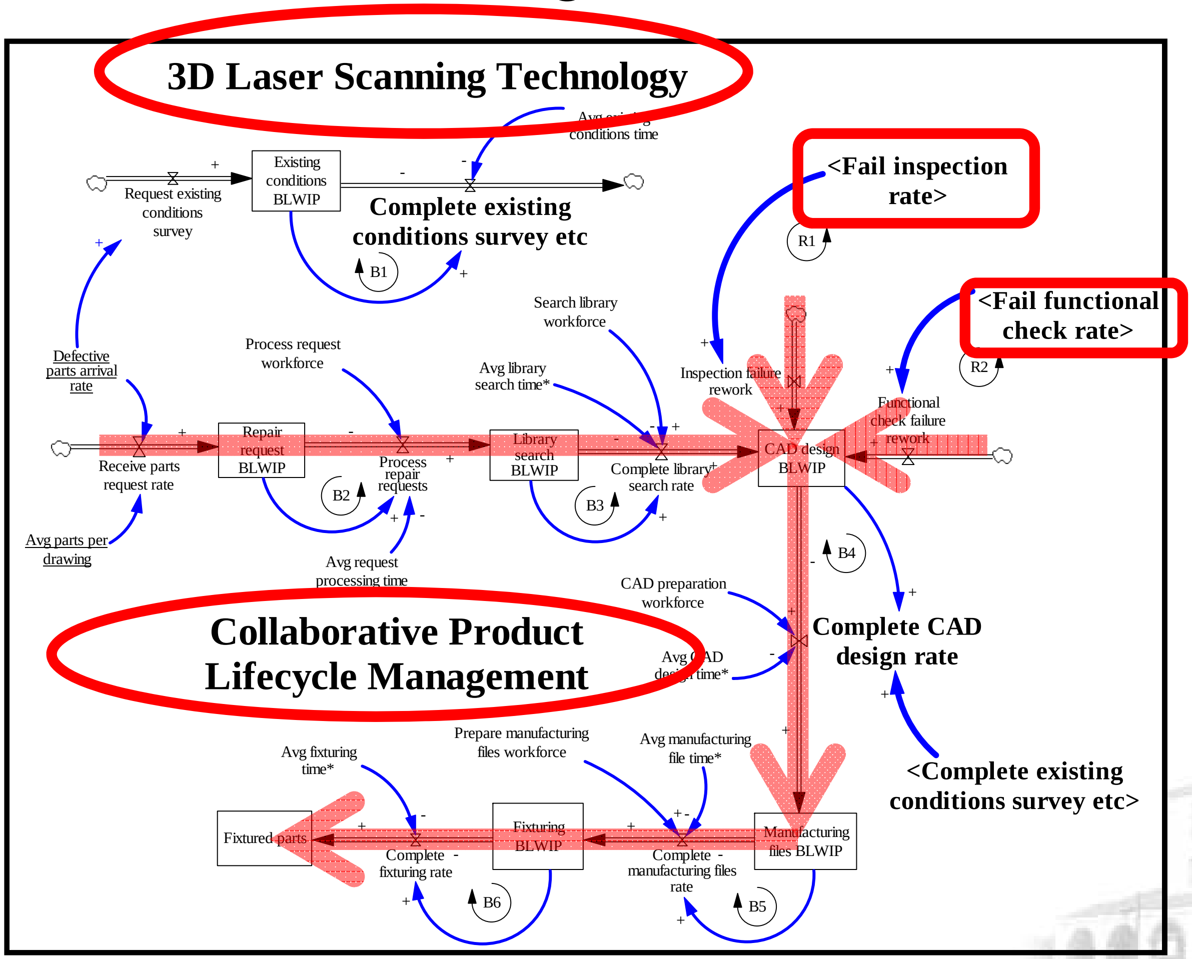
Additive Manufacturing by the US Navy



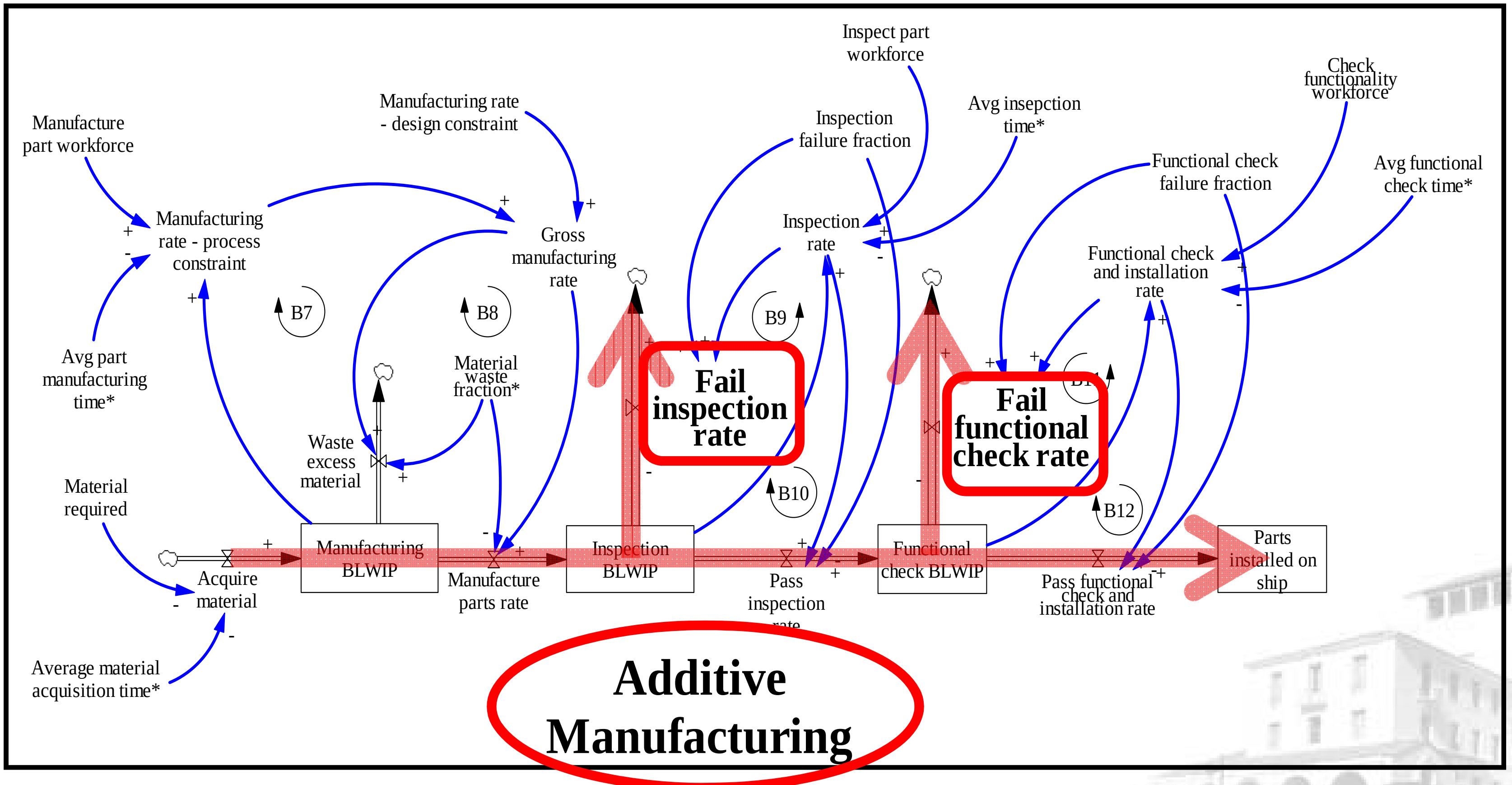
Depot-Level Machining Shop Process (Kenney, 2013)

2) System Dynamics Model

Information Processing for Additive Manufacturing



2) System Dynamics Model
Manufacturing Processing



3) Simulate Technology Adoption & Use Strategies: Scenarios Modeled

- **As-Is:** Current processes used at the depot where data was collected
- **To-Be#1:** Immature AM - AM used only to *create prototypes*
- **To-Be#2:** Immature AM *with CPLM* - used only to create prototypes
- **To-Be#3:** Immature AM *with 3DLST*, CPLM - used only to create prototypes
- **Radical#1:** *Mature AM with CPLM* - used to create both prototypes and final parts
- **Radical#2:** Mature AM, *3DLST,* CPLM - used to create both prototypes and final parts

4) Knowledge Value Added Models:
Sample Results

TO-BE#1- Immature AM

Processes	Benefit: Cost ratio	ROI (%)
Process request		
Search Library		
Prepare CAD & Add m		
Fixturing		
Manufacture part		
Inspect part		
Check functionalit		
Totals:		

RADICAL TO-BE#1- Mature AM + CPLM

Processes	Benefit: Cost ratio	ROI (%)
Process request	3.13	213%
Search Library	1.27	27%
Prepare CAD & Add Manuf	26.01	2501%
Inspect part	3.08	208%
Check functionality	0.48	-52%
Totals:	**8.87**	**787%**

5) Estimate Costs and Savings

	Prototype parts produced	**Final** parts produced
Old technologies	Prototype cost using old technologies	Final parts cost using old technologies
New technologies	Prototype cost using new technologies	Final parts cost using new technologies

The Four Cost Components of
Each Technology Adoption and Use Strategy

5) Estimate Costs and Savings: Results

Annual Production Costs and Savings

ROI = (Benefits-Costs) / Costs

Scenario Simulation Name	Scenario Description	Old techn. prototypes / year	New techn. prototypes / year	Old techn. final parts / year	New techn. final parts / year	ROI - old techn.	ROI - new techn.	Prototype cost (X$1,000)	Final parts cost (X$1,000)	Total Cost (X$1,000	Cost Savings from As-Is scenario (X$1,000)
As-Is	Current technologies	3,000	2,000	25,000	0	15%	30%	$43,469	$911,801	$955,27	**$0**
To-Be #1	Immature Additive Manufacturing	0	5,000	25,000	0	15%	12%	$46,716	$911,801	$958,51	**-$3,247**
To-Be #2	Immature Additive Manufacturing + CPLM	0	5,000	25,000	0	15%	92%	$27,379	$911,801	$939,18	**$16,090**
To-Be #3	Immature Additive Manufacturing + CPLM + 3DLST	0	5,000	25,000	0	15%	40%	$37,444	$911,801	$949,24	**$6,025**
Radical To-Be #1	Mature Additive Manufacturing + CPLM	0	5,000	0	25,000	15%	787%	$5,920	$118,392	$124,31	**$830,959**
Radical To-Be #2	Mature Additive Manufacturing + CPLM + 3DLST	0	5,000	0	25,000	15%	1391%	$3,520	$70,401	$73,92	**$881,348**

Prototypes only

Prototypes & Final Parts

<u>Result</u>: Very large cost savings are possible *<u>IF</u>* scale-up adoption and use.

5) Estimate Costs and Savings: Results

Annual Cost Savings of AM, CPLM, 3DLST, and Scaling Up Use

			1	2	3	4	5	
	Scenario Name	Scenario Description	Savings from As-Is scenario (X$1,000)	Savings from Additive Manufacturing (X$1,000)	Savings from Collaborative Product Lifecycle Management (X$1,000)	Savings from 3D Laser Scanning Technology (X$1,000)	Savings from scaling up adoption and use (X$1,000)	Notes on savings by specific strategies
1	As-Is	Current technologies	0					
2	To-Be #1	Immature Additive Manufacturing	-$3,247	-$3,247				←(To-Be#1)-(As-Is) Small scale use
3	To-Be #2	Immature Additive Manufacturing + CPLM	$16,090		$19,337			←(To-Be#2)-(To-Be#1) Small scale use
4	To-Be #3	Immature Additive Manufacturing + CPLM + 3DLST	$6,025			-$10,065		←(To-Be#3)-(To-Be#2) Small scale use
5	Radical To-Be #1	Mature Additive Manufacturing + CPLM	$830,959				$814,868	←(Rad. To-Be#1)-(To-Be#2) Scale up to produce final parts
6	Radical To-Be #2	Mature Additive Manufacturing + CPLM + 3DLST	$881,348		(Rad. To-Be#2)-(Rad. To-Be#2) → Large scale use	$50,390	$875,322	← (Rad. To-Be#2)-(To-Be#3) Scale up to produce final parts

Prototypes only

Prototypes & Final Parts

Conclusions & Implications

- Integrated new technology adoption and use can generate large savings (>$800m/yr). ***The US Navy should plan for and adopt these new technologies. {Practice}***
- Different technologies can save/cost more or less. ***An adoption strategy and plan based on analysis is needed. {Research}***
- Capturing very large savings requires large scale use. ***The strategy and plan should go beyond testing and trials to full scale use of new technologies. {Research & Practice}***

Issues for Future Research

- How much of what types of parts should the Navy make versus buy from industry?
- Requires changes in procurement regulations
- Transitions to steady –state use
  - Short term costs for adoption
  - Speed of adoption
  - Adoption locations

Questions
Comments
Discussion

5) Estimate Costs and Savings

Example Calculation of the Surrogate Revenue Streams for the Four-Part/Technology Types

	Prototypes			Final Parts		
	Production (parts/yr)	**Market comparable value** ($1,000/part)	**Surrogate revenue stream** ($1,000/yr)	**Production** (parts/yr)	**Market comparable value** ($1,000/part)	**Surrogate revenue stream** ($1,000/yr)
Old technologies	3,000	$10.5	**$31,500**	25,000	$42.0	**$1,050,000**
New technologies	2,000	$10.5	**$21,000**	0	$42.0	**$0**

As-Is Scenario