An Air Force S&T Directorate's View on Applying Systems Engineering (SE) Principles to its Programs

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Presentation Outline

- Background: Current Process
- Range of Different S&T Programs Covered by AFRL/RX SE
- IPPD analysis of Systems Engineering approaches for AFRL/RX programs
- Streamlined Systems Engineering Approach
- Case study: Materials and Manufacturing S&T
- Summary and Conclusions

Background: Current Processes

Development of Systems Engineering (SE)
in the Materials and Manufacturing Directorate
of the Air Force Research Laboratory (AFRL/RX)

AFRL/RX Baseline SE Process

- **Integrated Product & Process Development (IPPD)**
  - Combination of:
    - *Management Principles* – technologies aimed at transition
    - *Design Philosophy* – improve first time transition for prototypes
    - *Methodology* – understand and optimize technology value
    - *Tools* – statistical experiments…web enabled collaboration
  - Supports a Production Environment
  - Must be tailored to be effective in S&T
- **IPPD is the way one structures and performs a program, not something one does or in addition to.**

-IPPD for S&T Quick Reference,
Available at http://www.jamesgregory.com

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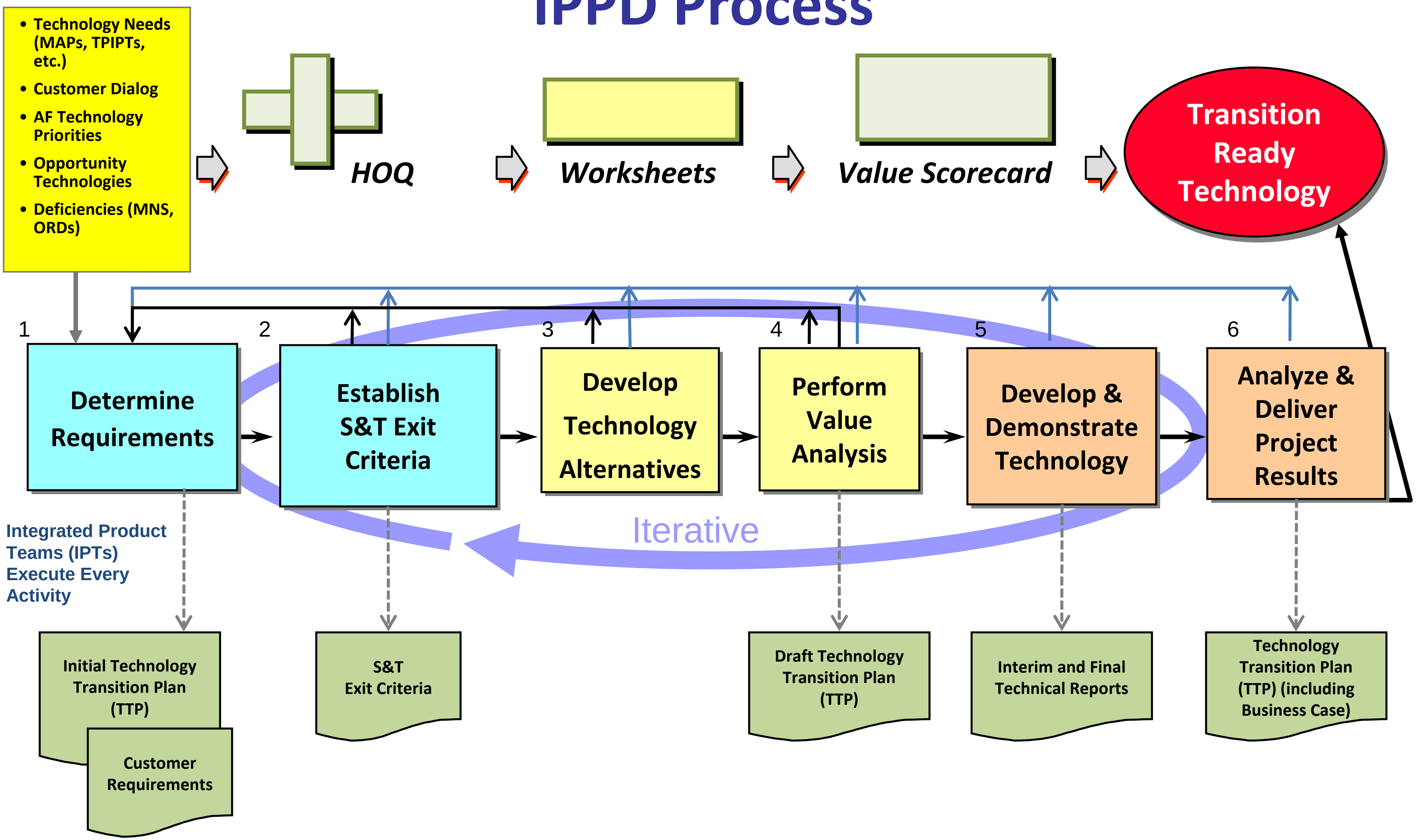
IPPD Process



The S&T IPPD Process

Range of Different S&T Programs Covered by AFRL/RX SE

AFRL Tailored SE Approach for Management Review of S&T Programs

Key Question	Basic Research	Applied Research	Advanced Research	ATD
1. Who is your customer?	Partial	Nearly Complete	Complete	Complete
2. What are customer's requirements?	Partial	Partial	Nearly Complete	Complete
3. How will you demonstrate you have met the requirements?	Partial	Partial	Nearly Complete	Complete
4. What are the technology options?	Extremely Limited	Nearly Complete	Complete	Complete
5. Which is the best approach?	Extremely Limited	Nearly Complete	Complete	Complete
6. What are the risks to developing the selected technology?	Partial	Partial	Nearly Complete	Complete
7. How will you structure your program to meet requirements and manage risk?	Partial	Nearly Complete	Complete	Complete
8. What is your business-based transition plan that meets customer approval?	Extremely Limited	Partial	Nearly Complete	Complete

Development of SE in RX

(derived from broad range of program types)

GOALS:
1. Improve Program Management Effectiveness and Efficiency
2. Improve Success of Tech Transitions & Transfers
3. Comply with AF and DoD Directives
4. Develop a Systems Engineering Culture

STRATEGY: Tailored SE for all S&T Programs

APPROACH:

Program Assessment → **Program Planning** → **Program Execution/ Portfolio Mgt**

- CGO IP (CP3 ish)
- Metamaterials (CP1 ish)
- Nano/Bio Inhouse (CP1 ish)
- Adv Battery (CP1 ish)
- Airbase Energy (CP2/3 ish)
- Laser Hardening (CP2 ish)
- Sustainment (CP1/2 ish)

Yellow: S&T Knowledge Generation (CP1);
Orange: Product Development (CP2);
Green: Urgent Need Response (CP3)

IPPD analysis of Systems Engineering approaches for AFRL/RX programs

IPPD analysis of Systems Engineering approaches for AFRL/RX programs

<u>Assumptions</u>:

- **The Customer** is Bob Rapson, Chief Engineer
- Pre-Milestone "A" research and development programs are identified based on **Program Objectives**, such as:
  - S&T Knowledge Generation (CP1)
  - Product Development (CP2)
  - Urgent Need Response (CP3)
- The **scope** of IPPD analysis includes:
  - Program Assessment
  - Program Planning
  - Program Execution
  - Program Transition.
- **Challenges** associated with large complex programs and portfolio management
- Include connects to **Program Management** such as: Key Performance Parameters, Work Breakdown Structures, and Earned Value Management.

IPPD analysis of Systems Engineering approaches for AFRL/RX programs

Form Team → **Determine SE Requirements & Desirements** → **Generate Alternatives** → **Evaluate Alternatives** → **Document Results**

- CP1
  - Assessment
  - Planning
  - Execution
- CP2
  - Assessment
  - Planning
  - Execution
- CP3
  - Assessment
  - Planning
  - Execution

- Team brainstorm different systems engineering approaches
  - Assessment
  - Planning
  - Execution

- Recommended systems engineering methodology for CP1
- Recommended systems engineering methodology for CP2
- Recommended systems engineering methodology for CP3

- USAF Problem / Goal
- Customer(s)
- SE Team Members
- List of Prioritized Reqts & Exit Criteria
- Description of Alternative Solutions
- Value Analysis

Challenge: There are many Alternative Methods that can be used to tailor SE Approaches

- Empirical Analyses
- Theoretical Analyses
- Statistical Analyses
- Design of Experiments
- Modeling and Simulation
- House of Quality and Quality Function Deployment
- Six Sigma and Taguchi, Scorecard (Balanced and/or Value)
- Analytic Hierarchy Process
- Earned Value Management
- "The SE Conversation": 8 Questions & AFRL/RX I 61-104
- Integrated Product & Process Development (IPPD)
- SETFST Approach: Quantitative (probabilistic) trade analyses
- SETFST with modeling and simulations (e.g. HELTP)
- System Architecture and Node Decomposition analyses
- Systems of Systems Analyses
- Joint Capabilities Integration & Development System (JCIDS) Methodology: FAA, FNA, & FSA

What is the “Best” SE Approach for a Laboratory?

- Suitable for a Range of Technical Challenges
  - Basic Research
  - Advanced Development
  - Transition to the Warfighter
- Overcome limitations & Retain strengths of IPPD-Based Approach
  - Extremely Valuable
    - Proven in major pilot programs
  - Tends to be expensive
  - Can be lengthy
  - Not (best option) for all types of S&T

Streamlined Systems Engineering Approach

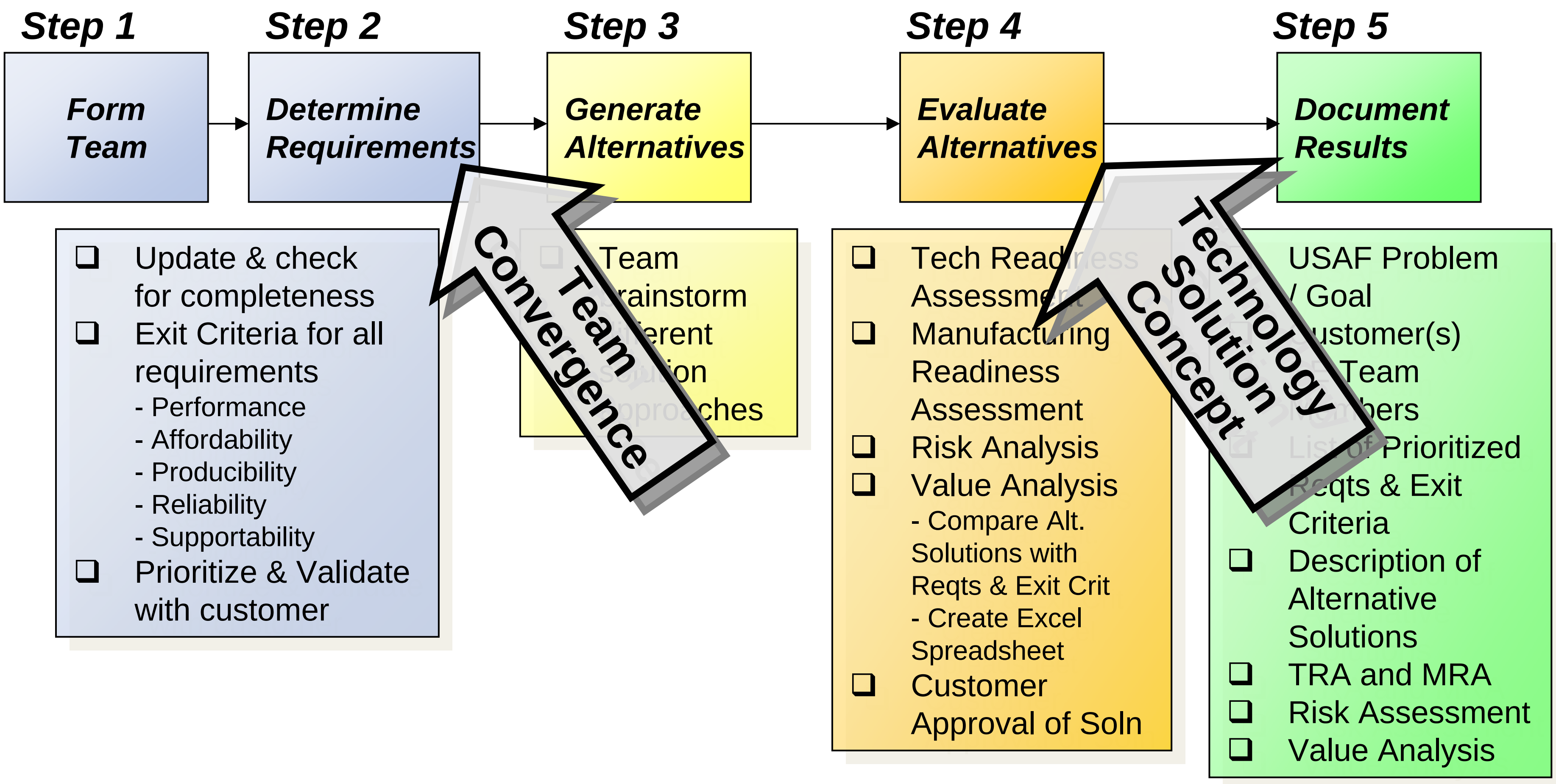
Integration of SE approaches into baseline CGO Initiative Program

Purpose

- Provides information and tools for good program management
- Provides baseline SE assessment process
- Provides testbed for initial evaluation of SE methods and tools
- **Lessons Learned**
  - Use existing proposal &/or briefing info to build a strawman SE framework
  - Two focused team meetings are usually sufficient
  - Providing checklists and other SE assessment examples are very useful
  - Involving Experienced Senior Engineer(s) is very helpful

Streamlined Systems Engineering Approach

Target Approach: Limited Number of Concise Team Meetings)



Case Study: Aerospace Ground Equipment Longevity Coating Evaluation for System Sustainment (AGELESS)

USAF Problem: Ground Equipment corrodes when exposed to weather elements

- Annual corrosion cost of $69,000,000 (and rising) directly associated with support equipment
- Labor and material costs to mitigate corrosion are increasing
- Workforce shaping has reduced available maintenance resources

Step 1: Form Team

- Form Team:
  - Principal Investigator and Funding Sponsor
  - Program Manager, Branch Tech Advisor, In-House Researcher
  - IPT Team: Program Manager, Potential Technology Recipients (SPO, JPO, DUST, MAJCOM), Branch Tech Advisor, and other technical, contractual, and financial expertise
  - IPT Team: Most key customers (Other interested TDs, program managers of related ATDs) identified and actively involved

- Lesson Learned – stay together "continuous"

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Step 2: Determine Requirements and Establish Exit Criteria

Determine Requirements

1. Minimize corrosion maintenance costs of non- powered aerospace ground equipment and other steel support equipment
2. Capability to coat inner “hard -to-reach” surfaces of a piece of equipment
3. User friendly coatings and coating processes
4. Avoid coatings that are harmful to environment
5. Capability for long lasting coatings
6. Qualified coating process
7. More that 1 tool in toolbox for combating corrosion

Establish S&T Criteria / Exit Criteria

a. Coating technologies that ensure adequate corrosion protection
b. Coating technologies that ensure adhesion to substrate
c. Surface profile for applying stencils/markings
d. Proper surface pretreatment process
e. Techniques for repairing damage to galvaniz ed coatings
f. Documentation of laboratory test results

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Step 2: Determine Requirements and Establish Exit Criteria

Before

Determine Requirements

1. Minimize corrosion maintenance costs of non-powered aerospace ground equipment and other steel support equipment
2. Capability to coat inner “hard-to-reach” surfaces of a piece of equipment
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Establish S&T Criteria / Exit Criteria

A. Coating technologies that ensure adequate corrosion protection
B. Coating technologies that ensure adhesion to substrate
C. Surface profile for applying stencils/markings
D. Proper surface pretreatment process
E. Techniques for repairing damage to galvanized coatings
F. Documentation of laboratory test results

After

Determine Requirements

1. Minimize corrosion related costs while not impacting other maintenance costs for non-powered aerospace ground equipment and other steel support equipment
   E, F, I, C, D
2. Capability to treat inner “hard-to-reach” surfaces of a piece of equipment G
3. Readily available, mature, demonstrated coating methods that don’t change metallurgical properties. (User friendly coatings and coating processes) C, D, H
4. Reduce environmental waste stream of current coating repair processes (Avoid coatings that are harmful to environment) 1/3 impact reduction (ref E)
5. Clean Appearance J
6. Different than existing approach I, E, F, G
7. at least as damage tolerant as current coating system
   E, A, B

Establish S&T Criteria / Exit Criteria

A. Coating technologies that ensure adequate corrosion protection
B. Coating technologies that ensure adhesion to substrate
C. No surface prep changes for applying stencils/markings
D. Utilize existing Repair techniques
E. Documentation of laboratory test results that compare performance with baseline paint
   - ASTM G1 boldly exposed
   - ASTM G44 Alternate immersion
   - Field testing/beach exposure
F. Meet or exceed MIL STD 808
G. Apply to specification thickness, minimum of 4 ft , and 1 inch internal diameter
H. Qualified coating process in accordance with industrial standards
I. Need 2X, Want 10X coating life improvement with capability to do touch-up repairs
J. Repair looks the same as original; match color, texture, gloss

Step 3: Generate Alternatives

Before

Develop Technology Alternatives

- Coatings conforming to MIL-PRF-26915
- Metallization (aka Metal Wire Arc Spray)
- Hot-dip galvanization
- ????
- ????

After

Develop Technology Alternatives

- Coatings conforming to MIL-PRF-26915
- Metallization (aka Metal Wire Arc Spray)
- Hot-dip galvanization
- Build Stainless Steel Equipment
- Paint over Zinc coating
- Electrogalvanization

Step 4: Evaluate Alternatives (Conduct TRA, MRA, & Risk Assessment on Feasible Solutions)

1. Identify Critical Technology Elements and TRL for each Element
2. Identify Critical Manufacturing Processes and MRL for each Process
3. Assess risk associated with producibility, reliability, affordability, and maintainability. Assess risk associated with system integration.

Technology Alternatives:

- Coatings conforming to MIL-PRF-26915
- Metallization (aka Metal Wire Arc Spray)
- Hot-dip galvanization
- Build Stainless Steel Equipment
- Paint over Zinc coating
- Electrogalvanization

Step 5: Document Results

A Key Benefit of SE in the S&T Environment:

Items Documented:

- USAF Problem / Goal
- Customer(s)
- SE Team Members
- List of Prioritized Requirements and Exit Criteria
- Description of Alternative Solutions
- TRA & MRA
- Risk Assessment
- Value Analysis

Case Study: Materials and Manufacturing S&T

Aerospace Ground Equipment Lifetime Coating Evaluation for System Sustainment (AGELESS)

CGO Initiative Program

16 May 2008

THE AIR FORCE RESEARCH LABORATORY
LEAD | DISCOVER | DEVELOP | DELIVER

Materials & Manufacturing Directorate
Systems Support Branch

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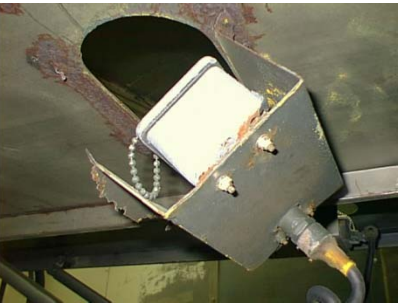
AGELESS
Overview



Project Lead: Lt Ben Wilkerson

Team: Mr. Corey Bliss, MSgt Royce Stamps, SMSgt Byron Wilson, Mr. Dennis Douglas, Mr. Larry Perkins

Start/End Dates: 19 March 07 – 30 Sept 08

Amount Funded: $74.1K

Completed Milestone: 2/3

General Description of Technical Work:

- Galvanization is a method of applying a thin coating of zinc onto a B-4 maintenance stand at Hill AFB
- Conduct full-scale galvanization of non-powered AGE
- Evaluate the costs associated with infrequent painting of AGE/SE vs. a one-time galvanization
- Perform select laboratory tests on galvanized steel with respect to other coating technologies (MIL-PRF-26915 (informally known as "Zinc-Rich Primers and Metallization (a.k.a. Metal Wire Arc Spray (MWAS))) to ensure adequate
  - Corrosion protection
  - Adhesion to substrate
  - Surface profile for applying stencils/markings

Motivation/Need/Payoffs:

- Annual corrosion cost of $69,000,000 (and rising) directly associated with support equipment
- Labor and material costs to mitigate corrosion are increasing
- Workforce shaping has reduced available maintenance resources
- Extend coating life, but not necessarily extend of support equipment life
- Send final recommendation to 642nd Combat Sustainment Group for analysis
  - Todd Balducci and Traci Messick

Overall Programmatic Approach:

- Phase 1 – Demo galvanization on existing non-powered AGE (Out-house)
- Phase 2 – Supplemental lab and field testing to verify/validate coating performance, address issues of reparability (In-house)
- Phase 3 – Technology transition efforts (In-house)

VALUE ANALYSIS

Alternative Technology Solutions

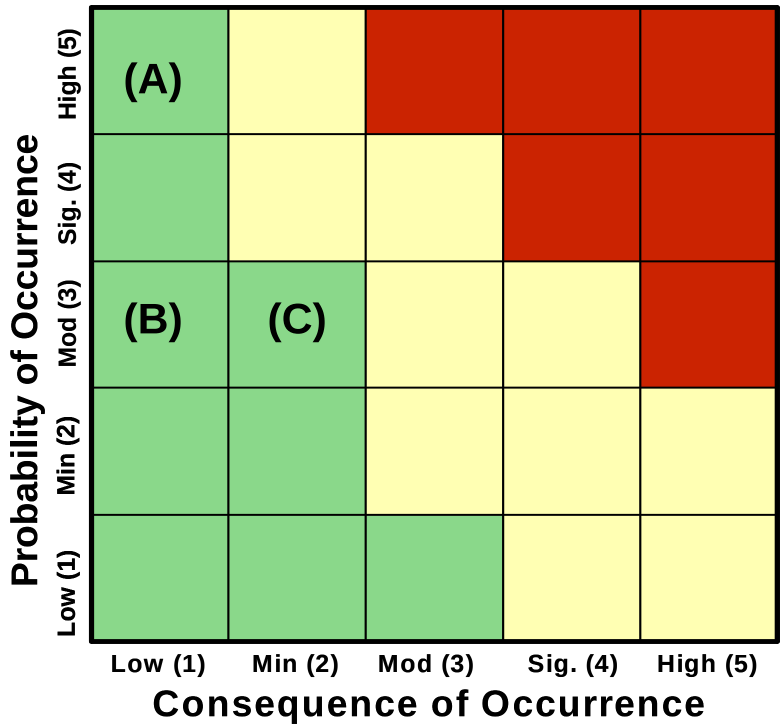
Prioritized Requirements

Prioritized Requirements		Coatings conforming to MIL-PRF-26915	Metallization (aka Metal Wire Arc Spray)	Hot-dip galvanization	Paint over Zinc coating	Electrogalvan-ization
1. Min Corrosion Costs		zero	minus	plus	minus	plus
2. Reduce Environmental impact		zero	plus	plus	minus	plus
3. Damage Tolerant		zero	plus	plus	zero	plus
4. Available & Mature Method		zero	zero	zero	zero	zero
5. Clean Appearance		zero	minus	zero	zero	zero
6. Different Approach		zero	plus	plus	zero	plus
7. Treats hard-to-reach surfaces		zero	minus	zero	minus	minus

AGELESS

Program Risk Assessment

Risk / Mitigation (PxC)
A. Unidentified way to repair Hot Dipped Galvanization (HDG) (5x1) *Contact subject matter experts at the Corrosion Office & AGE Office for solutions* *Work with the transportation industry to determine fix*
B. Inability to match current Galvanization coating color (3x1) *Work with the transportation industry to determine way to match current coating color*
C. Logistical aspects of transporting aerospace ground equipment to and from hot-dip galvanization vendors (3x2) *The majority of AGE is contracted out; therefore, the logistics has already been completed* *HDG of AGE should only be completed on equipment coming from the manufacturer*



AGELESS

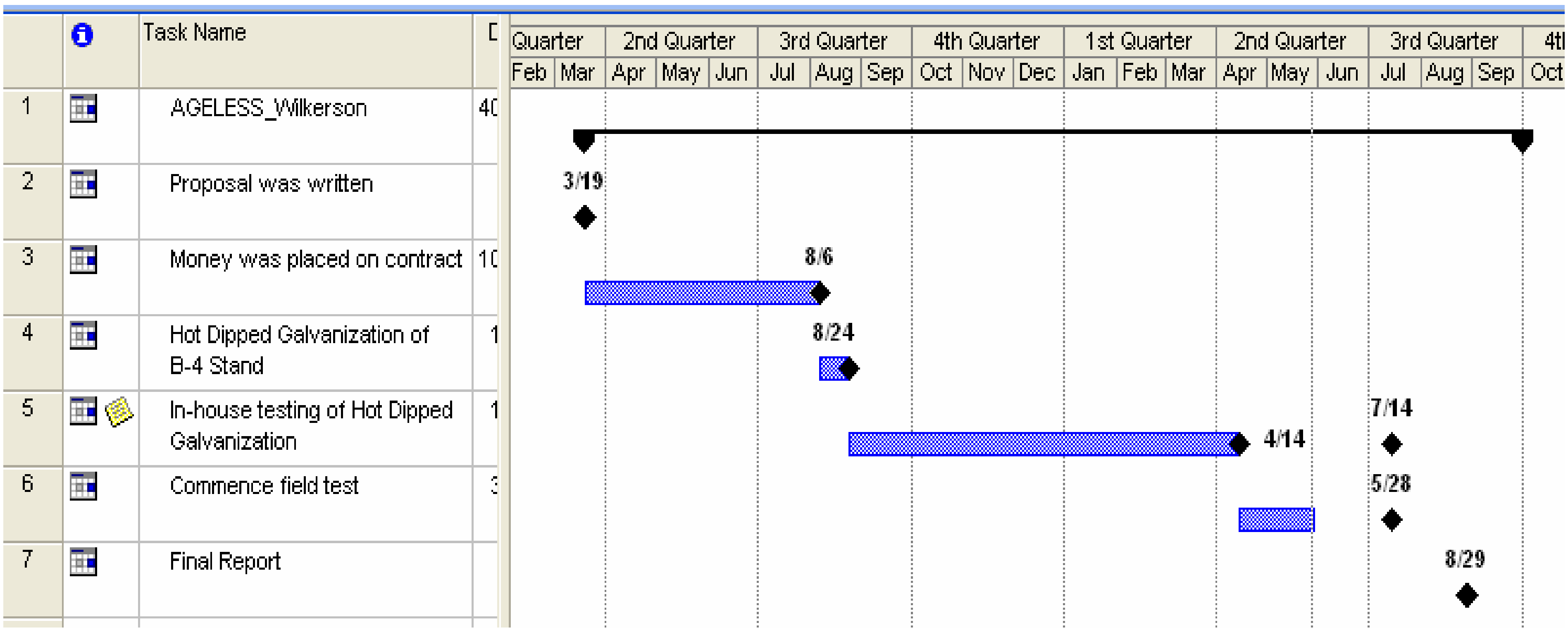
FA8601-06-D-0013 University of Dayton Research Institute

ASSESSMENT AREA/STATUS E=EXCELLENT (GREEN) S=SATISFACTORY (BLUE) M=MARGINAL (YELLOW) U=UNSATISFACTORY (RED) NA=NOT APPLICABLE											
ASSESSMENT AREA	E	S	M	U	NA	ASSESSMENT AREA	E	S	M	U	NA
a. Technical Performance	x					e. Contracting	x				
b. Financial		x				f. Staffing	x				
c. Cost vs. Accomplishment	x					g. Testing	x				
d. Progress vs. Schedule	x					h. Transition and Other		x			

- The program is on schedule and on budget
- The Galvanized B-4 maintenance stand was sent from Hill AFB to Eglin AFB
  - Stand was moved to a more corrosive environment
- All lab testing has been completed
  - Better repair procedure needs to be identified in future effort
- A trip to Eglin AFB is scheduled for the beginning of June to gather field data for final report
- Transition efforts through the Air Force Corrosion and 642nd Combat Sustainment Group have been made

AGELESS

Schedule



AGELESS

Summary

- Program was successfully completed.
  - Maintained constant communications with Air Force Corrosion, the 642nd Combat Sustainment Group , and PACAF.
  - Revaluating the program allowed for a better understanding of what steps are required to have a successful program.
  - Lab testing was completed
  - Lab results were presented to the Aircraft Ground Support Equipment Working Group (AGSEWG)
  - The Galvanized B-4 maintenance stand was sent from Hill AFB to Eglin AFB for field testing.

- Transition
  - Transitioned through the Air Force Corrosion Prevention and Control Office and the 642nd Combat Sustainment Group.

Systems Engineering Summary and Conclusion

AFRL/RX Systems Engineering Summary and Conclusions

- Adapting Systems Engineering to Laboratory Programs
  - Affordable, Time Efficient, Recognized as Beneficial
- Baseline Approach: IPPD
- Tailor SE Methods to Different Types of S&T programs
- Initial Case Studies have shown Applicability and Value at Different S&T Levels
- Ultimate Goal: Baseline Streamlined Process followed by Detailed Analysis, as Appropriate