Systems Engineering Transformation
Surrogate Pilot Experiments: Doing Everything in Models to Demonstrate the Art-of-the-Possible

Sponsor: NAVAIR and CCDC-AC

By
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Abstract

• NAVAIR characterized the Systems Engineering Transformation (SET) Framework for a Digital Engineering (DE)-enabled acquisition. This presentation discusses the Surrogate Pilot use cases, models and lessons learned in assessing the SET Framework for collaboration between government and industry.

• This is an evolving version of a briefing that summarizes the Systems Engineering Transformation (SET) Surrogate Experiments. It provides an overview to set the context of the SET Framework concept and Functional Areas. Research is one of the functional areas that was defined along with an evolving set of objectives that are being used to guide the experiments, and trace the results to the objectives.

• These experiments are being conducted by a team of NAVAIR Subject Matter Experts, SERC Collaborators from Stevens Institute and Georgia Tech, and a Surrogate Contractor from Altair. The ongoing results and lessons learned are captured on the All Partners Network (APAN.org @ https://community.apan.org/wg/navair-set/set-surrogate-pilot/) and being shared with Industry and Government.

• This briefing is Distribution A.
Research Tasks and Collaborator Network

RT-48
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Rob Cloutier (Co-PI) - Stevens
Eirik Hole - Stevens
Gary Witus – Wayne State

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Roger Jones – Stevens
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Chris Snyder - Stevens
Gregg Vesonder – Stevens (Phase I)
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Kunal Batra (Grad) – Stevens
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• WHAT: Context and Scope of NAVAIR SE Transformation

• HOW: Use Evolving Surrogate Pilot and Experiments to Demonstrate Art-of-the-Possible

• HOW: Transformation Elements Moving from Documents to Models

• HOW: Phase II Objectives (FY19) Aligns with SE Transformation (SET) Priorities

• HOW WELL: Contributing Modeling Examples to Support Workforce Development demonstrating Art-of-the-Possible
WHAT:
Context and Scope of NAVAIR SE Transformation

Research in the Context of
Surrogate Pilot Experiments
Capability Based Acquisition - Outpacing the Threat
Digital Thread enables rapid delivery of Integrated Capabilities

Integration and Interoperability (I&I)

- Integrated Warfare Analysis establishes CONEMPS and Effects-Chains
- SoS MODEL: CONEMPS and Effects Chains are modeled at the System of Systems (SoS) level

SE TRANSFORMATION

System models form "Constructive" basis for LVC M&S environment

SYSTEM MODELS

1. Structure
2. Behavior
3. Requirements
4. Parametrics

Capabilities-Based T&E

- Constructive
- Virtual
- Live

LVC-based Training maximizes Fleet proficiency

Focus is Here

Constructive Virtual Live

Focus is Here

NAVAIR Public Release 2017-370. Distribution Statement A – “Approved for public release; distribution is unlimited”
Surrogate Pilot focus is on Characterizing, Assessing, and Refining SET Framework for Model-Based Acquisition

- Elimination Transformation of paper CDRL artifacts and large-scale design reviews
- Continuous insight/oversight via digital collaborative environment and interaction with the Single Authoritative Source of Truth

**SET Framework Concept Initially Rolled Out 2016**

**CDRL:** Contract Data Requirements List

NAVAIR Public Release 2017-370. Distribution Statement A – “Approved for public release; distribution is unlimited”
Research and Surrogate Experiment contributes broadly to SET Functional Areas
HOW:
Use Evolving Surrogate Pilot and Experiments to Demonstrate Art-of-the-Possible

• Doing “Everything” in Models to show we can
• Operating in a Collaborative Environment
• Using an Authoritative Source of Truth
Surrogate Pilot Scenario: Skyzer UAS & Launch and Recovery for Landing Gear Deep Dive

Graphical CONOPS Scenario: Search & Rescue

Performance constraints force Multi-physics Design considerations - similar to Bell Eagle Eye

Skyzer System & Mission Models developed using SysML

Phase II is adding ship-based Launch and Recovery Capability & Deep Dive supports Airworthiness Use Case

NAVAIR Public Release 2019-443. Distribution Statement A – “Approved for public release; distribution is unlimited”
Skyzer is Experimental UAS System using Authoritative Source of Truth (AST)

Mission Models
System Models
SOW Models
Evaluation Model
Based on Standards

Proposal for Design Models focused to demonstrate aspects for Producability Decisions involving Multi-physics

Surrogate Pilot Use Cases (UC)
Collaboration in Authoritative Source of Truth UC

Assess SE Framework Concept
We are Collaborating in AST

RFI
RFP
GFI
RFP Response Extends GFI

Project Plan Model UC
Mission Model UC
System Model UC
Contractor(s) System Model(s) UC
Contractor Design Model UC
Source Selection UC & Models
Phase 1 Complete
Phase 2 – Work Elements 3 & 4

Everything done in models to demonstrate “Art of the Possible”

Uses
Uses
Links

SSR 2019
GFI: Government Furnished Information

NAVAIR Public Release 2018-194. Distribution Statement A – "Approved for public release; distribution is unlimited"
Continuous Updates of Discussion Threads Provided on Public All Partners Network

- Briefings
- Videos
- Models
- Discussion threads
- Instructs to see models on AWS

Access at:
https://community.apan.org/wg/navair-set/set-surrogate-pilot/

NOTE: Currently updating Research Group for Phase II
https://community.apan.org/wg/navair-set/research/
HOW:
Transformation Elements
Moving from Documents to Models

• Developing/demonstrating Methods for Mission and System models
• Using models collaboratively in Authoritative Source of Truth
• Using OpenMBEE/DocGen to Generate Views for Stakeholder and Discipline-Specific Subject Matter Experts
Skyzer Demonstrates Formalizing the Use of Models and Methods for the SET Framework Elements

Phase II focused on Elements 3 & 4 of SET Framework: How to reduce time by using models to better understand a maturing design.

Operational Models

User Capability Model (aka Mission Model)

System Model
- Initial System Model
- Final System Model

Element 1

System Model is Authoritative Requirements Source (e.g. Gov’t Specification)

Acquisition Agreement
- Main Contract
- Sub Contracts

Discipline-Specific Models (Mechanical, Electrical, SW)

Component 1 Model
- Component 2 Model
- Component n Model

Element 4

SoS Level

System Level

Sub-System 1 Model
- Sub-System 2 Model
- Sub-System n Model

Element 3

Functional Baseline

Element 2

Operational Models

Other Business Models
- Personnel, support, training, etc.

Warfighter

Acquirer

Prime Contractor

Sub Contractors

NAVAIR Public Release 2017-892. Distribution Statement A – “Approved for public release; distribution is unlimited”
“Full Stack” of Models using Digital Signoff for Transformed SETR Criteria Represented in a Model

Reference models characterize reusable information and process

- ASRM with NAVSEMM Model
- Airworthiness Model
- CDRLs Model
- CBT&E / MBTD Model
- MBTD Process

NEW: Reliability and Maintainability

Process, Information model & View/Viewpoints for V&V

Requirement for MIL Std. 516C tailored to program

Models SETR criteria with Digital Signoff for SRR baseline

Calculates Performance Margins for KPPs in RFP

Using and Tailoring Reference Models

- “Full Stack” Skyzer
- Mission Model
- UAS System Model
- USES
- NEW: L&R Sys Model
- RFP Response Model
- Instance of SRR-II Model
- NEW: Instance of Airworthiness Model
- NEW: Instance of CBT&E / MBTD Model
- RFP Evaluation Model

Subsystems

NEW: Instance of ASRM with NAVSEMM Model

NEW: Instance of Skyzer
Model Organization – All Models Linked to Establish Authoritative Source of Truth
Leverage Capabilities of OpenMBEE as Part of Integrated Modeling Environment

Model Development Kit/DocGen
View and Viewpoint Hierarchy

Model Management System

MMS repository

View Editor

Visualization in View Editor
(allow edits to be pushed back into model)
Elements of Authoritative Source of Truth

**Government-side of Authoritative Source of Truth (AST) for Surrogate Pilot**

- View Editor*
- Cameo Collaborator
- Teamwork Cloud
- MMS*
- IoIF**
- Amazon Web Services (AWS)

**Users Anywhere**

- No Magic Clients with MDK/DocGen* (all team members)
- Stevens**

**Surrogate Contractor+**

- View Editor*
- Teamwork Cloud
- MMS*
- IoIF??
- Activate+
- Inspire Unlimited+
- MDAO+
- Display Manager+
- CAD/CAE+
- Other+

**OpenMBEE***
- Model Management System (MMS)
- View Editor
- Model Development Kit (MDK)/DocGen
**Integration and Interoperability Framework**

**Others**

- Docker Installer (script installs OpenMBEE)
- Internet
- Stevens**
- View Editor*
- Model Center
- Teamwork Cloud
- MMS*
- IoIF**
- Other Tools & Simulation

---

*Model Management System (MMS)
*View Editor
*Model Development Kit (MDK)/DocGen
**Integration and Interoperability Framework
**No Magic Clients with MDK/DocGen* (all team members)
Example View and Viewpoint Hierarchy Used by DocGen

Views define “Document” Structure

View exposes Model Elements

Viewpoints is “program” to extracts specific information from exposed model element to generate View
Example: View Editor shows Skyzer Mission Model View

Model information can be “edited” in View Editor (e.g., by SME) and pushed back into Model (Fundamental to AST)
Mission Requirements Refined into Behaviors and Analyzed through Simulations in Skyzer System Model

- State Machine Simulation in System Model supports analysis for understanding/visualizing dynamic behaviors – getting the right model and getting the model right
### Skyzer Mission and System Requirements Traceability in Skyzer System Model

#### Figure 6.1. Requirements Satisfiability

<table>
<thead>
<tr>
<th>Legend</th>
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<tbody>
<tr>
<td>Satisfied By</td>
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<table>
<thead>
<tr>
<th>System Model</th>
<th>Subsystems</th>
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<tbody>
<tr>
<td>Skyzer UAV</td>
<td>System</td>
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<tr>
<td>Skyzer</td>
<td>Elements</td>
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<td>strap-on</td>
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<tr>
<th>Mission Requirements (Skyzer MAO: Skyzer MAO - Mission)</th>
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<tr>
<td>1. Mission Requirements (Skyzer MAO: Skyzer MAO - Mission)</td>
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<tr>
<td>1.2 Functional Requirements</td>
</tr>
<tr>
<td>1.2.1 Skyzer System Functional Requirements</td>
</tr>
<tr>
<td>1.2.1.1 Maintain/Deploy Disposable</td>
</tr>
<tr>
<td>1.2.2 UAV Functional Requirements</td>
</tr>
<tr>
<td>1.2.2.1 Autonomous navigation to search areas specified in mission</td>
</tr>
<tr>
<td>1.2.2.2 Autonomous navigation to ship recovery hold position</td>
</tr>
<tr>
<td>1.2.2.3 Autonomous execution launch flight path plan from start point</td>
</tr>
<tr>
<td>1.2.2.4 Autonomous landing at commanded position</td>
</tr>
<tr>
<td>1.2.2.5 Autonomous home on 460 mgc beacon to locate drop site</td>
</tr>
<tr>
<td>1.2.2.6 Autonomous hover at commanded position</td>
</tr>
<tr>
<td>1.2.3 UAV Fly Patterns</td>
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<tr>
<td>1.2.3.1 Launch/Recovery System Functional Interface</td>
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<tr>
<td>1.2.3.2 Disengage RAST restraint</td>
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<td>1.2.3.3 Engage RAST restraint</td>
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<td>1.2.3.4 Ground Station Functional Interface</td>
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<tr>
<td>1.2.3.5 Receive ground station commands</td>
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<tr>
<td>1.2.3.6 Image Resolution</td>
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<td>1.2.3.7 Communication Range</td>
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<td>1.2.3.8 Transmission Quality</td>
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<td>1.2.3.9 UAV Transmission Bandwidth</td>
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<tr>
<td>1.2.3.10 Execute ground station commands</td>
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<td>1.2.3.11 Store ground station mission plan</td>
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<tr>
<td>1.2.3.12 Receive ground station mission plan</td>
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<tr>
<td>1.2.3.13 Power up on command of ground station</td>
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<td>1.2.3.14 Power down on command of ground station</td>
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<td>1.2.3.15 Report execution of ground station commands</td>
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<tr>
<td>1.2.3.16 Transmit current position to ground station</td>
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<tr>
<td>1.2.3.17 Power down on ground crew emergency shut off</td>
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<tr>
<td>1.2.3.18 Acknowledge receipt of ground station commands</td>
</tr>
<tr>
<td>1.2.3.19 Transmit video or still images to ground station</td>
</tr>
<tr>
<td>1.2.3.20 Relay distress vessel/individual VHF communication</td>
</tr>
<tr>
<td>1.2.3.21 Communicate via LOS or BLOS depending on the distance</td>
</tr>
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<tr>
<td>1.1 Performance Requirements</td>
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<tr>
<td>1.1.1 Max Speed</td>
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<tr>
<td>1.1.2 Cruise Speed</td>
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<tr>
<td>1.1.3 Max Payload Weight</td>
</tr>
<tr>
<td>1.1.4 Operational Radius</td>
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<tr>
<td>1.1.5 Recovery Condition</td>
</tr>
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<td>1.1.6 Operational Altitude</td>
</tr>
<tr>
<td>1.1.7 UAV Operation Period</td>
</tr>
</tbody>
</table>

| System Requirements |

**Traceability**
RFP Response Extends and Refines Skyzer System Model provided by Government as GFI
View of RFP Response Hyperlinks to Discipline-Specific Models Provided in Generated View
Surrogate Pilot RFP Response in View Editor

2.2.1 Propulsion Subsystem
• Research currently investigating how to do reviews and Digital Signoffs in Model for Transforming CDRL/DIDs
Transform CDRLs and DIDS using Digital Signoff in Model Through View Editor

1) Enable Editing
2) Add Risk
3) Add Approval Status
4) Template tailorable

Digital Signoff get “pushed” back into Model (continuing theme of AST)
Digital Signoff for SRR-II Criteria in Skyzer RFP View

Model artifact provides evidence for SETR criteria

Criteria in existing NAVAIR Systems Engineering Technical Review (SETR) for SRR (can Digital Signoff subsume SETR)
Digital Signoff of Source Selection Technical Evaluation Done In the Model that is Part of Authoritative Source of Truth

2.1.1 Technical Cross Reference Sign Off

<table>
<thead>
<tr>
<th>Approved Elements</th>
<th>Risk</th>
<th>Approval Status</th>
<th>Approved By</th>
<th>Comment</th>
</tr>
</thead>
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<tr>
<td>Air Vehicle Performance; Operational Radius</td>
<td>medium</td>
<td>approved</td>
<td>Donald Polakovic</td>
<td>Evaluation Worksheet: Overall the aircraft far exceeds the operational radius KPP. Potential Strengths: Very significant margin for additional mission capability and versatility. Weaknesses: Aircraft may be larger and more expensive than necessary to do the mission. Deficiencies: None Uncertainty: Performance analysis could not be reviewed in its entirety due to some inconsistent data. Margins seems large enough to cover this however.</td>
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<td>UAS Capability</td>
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<td>N/A</td>
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<tr>
<td>Air Vehicle Performance; Endurance</td>
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<td>approved</td>
<td>Donald Polakovic</td>
<td>Evaluation Worksheet: Overall the design appears to have sufficient endurance, with adequate development margin.</td>
</tr>
</tbody>
</table>
Thank you!

Dr. Mark Blackburn
Principal Investigator
Member of SERC Research Council
Member of OpenMBEE Leadership Team
School of Systems & Enterprises
Systems Engineering Research Center
Stevens Institute of Technology