PEO Missiles and Space Systems Engineering Methods

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EXECUTIVE SUMMARY

This is the final technical report of the Systems Engineering Research Center (SERC) research task RT187. This research task (RT) addresses research needs associated with evolutionary systems that are in wide use and are being actively integrated on numerous platforms today. During FY2017, the Program Executive Office (PEO) Missile and Space Office of the Chief Engineer began to push the implementation of the Model Based Enterprise (MBE) and Model Based Systems Engineering (MBSE). He supported this push with local training on the use and implementation of MagicDraw as one tool in the MBE suite. The PEO push was further supported by the Joint Attack Munition Systems (JAMS) Project Office (PO) Deputy Program Manager and Chief Engineer. They established an ad hoc group to further investigate the implementation of MBE and the various tools available. This backdrop coupled with the tasks proposed in RT187 led to the following accomplishments.

- The initial MagicDraw installation in JAMS PO, with subsequent training and additional installations.
- The initial Windchill installation for JAMS PO with workflows and MagicDraw integration planned.
- The initial use of structured blue scanning for computer aided design (CAD) model validation in JAMS PO.
- The initial model based physical configuration audit (PCA) experiment in JAMS PO.
- The establishment of an analysis working group between JAMS PO and their prime contractor.
- Development of a case study focused on MBSE methods, processes, and techniques (MPTs) for non-standard launchers with goal of transitioning results to new start launcher development.
- Membership in International Council on Systems Engineering (INCOSE)- National Agency for Finite Element Methods and Standards (NAFEMS) System Modeling and Simulation Working Group(SMSWG).
- Connections within the software industry to enable engineering analysis integration with MagicDraw SysML models.
- Connections within the software industry to integrate CAD model validation software with Windchill.

INTRODUCTION

The Chief Engineer of PEO Missile and Space expressed a strong desire to implement the MBE and MBSE in a FY2017 briefing. This consisted of a suite of tools including MagicDraw, Windchill, Microsoft Project, and ARM9. He supported this push with local training on the use and implementation of MagicDraw building on the good experience of other Project Managers within the PEO. The push was further supported by the JAMS PO Deputy Program Manager and Chief Engineer. They established an ad hoc group to further investigate the implementation of MBE and the various tools available. Membership in this ad hoc group and RT187 led to the initial installation of MagicDraw, and eventually Windchill, within the JAMS PO. Although not fully implemented, there are now additional installations within JAMS PO and there is a plan to demonstrate the potential benefits through the non-standard launchers integrated product team (IPT) and a new start launcher development program, showing benefits of model reuse.

The direction taken in this investigation is primarily mechanical based looking for tools and methods to increase efficiency in development and reuse of CAD models and engineering analysis models and results.

OBJECTIVES

The objective taken from RT187 follows: The objective of this effort was primarily mechanical and was designed to look at the downstream engineering and develop methods of model and data reuse for the typical evolutionary acquisition strategy that JAMS PO has been following. After identifying the models and data that are used in the downstream engineering, a backwards-planning methodology will be applied to ascertain if there are logical milestones that the model development and data acquisition could be applied to for future acquisitions. If so, this could be the efficient, cost effective path to Future Vertical Lift (FVL) weapons integration.

SCOPE

The scope of this investigation was to develop MPTs that could be applied to current and future JAMS projects and programs of record (POR).

RESEARCH EVENTS AND DELIVERABLES SUMMARY

The following events were attended:

EVENTS

MSC Software telecon to discuss linking finite element analysis and multibody dynamics analysis with SysML and Magic Draw. 25 September 2018, Huntsville, Alabama.

JAMS Technical Interchange Meeting (TIM), 30 Oct –1 Nov, 2017 and 9-10 July 2018, Orlando, Florida.

American Society of Mechanical Engineering (ASME), Verification and Validation Subcommittee (V&V10) Meeting. 2 Nov 2017, Dayton, Ohio.

INCOSE-NAFEMS Collaborative SMSWG telecon, 22 January 2018.

Model based PCA investigation at Arnold Defense. 20-22 March 2018, Arnold, Missouri.

National Institute of Technology (NIST) MBE Summit. 2-5 April 2018, Gaithersburg, Maryland.

ITI Global telecon to discuss CAD model validation in conjunction with Windchill 17 May 2018, Huntsville, Alabama.

NAFEMS Conference on Advancing Analysis and Simulation in Engineering (CAASE 2018). 5-7 June 2018, Cleveland, Ohio.

Joint Attack Munition Systems (JAMS) SAIC TIM, 31 July 2018, Indianapolis, Indiana.

JAMS PO – Aviation and Missile Research, Development, and Engineering Center (AMRDEC) Windchill Kickoff Meeting, 13 August, 2018, Redstone Arsenal, Alabama.

DELIVERABLES

- Technical and Management Work Plan (Month 1)
- Project Kickoff Meeting after Award (Month 1)
- Bi-monthly Status Report (Month 2,4,6,8,10, and 12)
- Monthly Financial Report
- Final Technical Report and Out Brief (Month 12)
- Any related technical data, software, research papers, or journal articles developed as a result of the research (Month 12)

PEO MISSILES AND SPACE METHODS DEVELOPMENT

The objective was to create a closer connection between downstream engineering and the SE and to provide connectivity with past analysis and models. Initial efforts involved reaching out to the primary software vendor used by AMRDEC Platform Integration to investigate their ability to connect analysis codes and results files with SysML. Through a series of telephone conversations, this appears to be possible and should be further pursued. The goal is to eventually have connectivity for some analytical models to allow the SE to be able to change requirements in MagicDraw and have analysis run in the background to find solutions for a very limited number

of parts and requirements. One case in particular is the springs in the launch rail that control retention force. This is a well bounded problem and the parameters could be established sufficiently in SysML to make this calculation.

The other area of great interest is technical data package (TDP) creation and updating as defined by MIL-STD-31000. The numerous non-standard launcher configurations are a natural for CAD system configurations using common parts. The greater challenge is that most of the non-standard launchers are not part of a production contract. This poses the problem that they cannot drive changes to production hardware, but they can be affected by production changes. A proposed solution is discussed in a later section.

Another area that gained unexpected attention is that of model based PCA. This is another area that could benefit from the MBE coupled with evolving validation techniques such as structured blue light scanning. An experiment was conducted at the rocket pod manufacturer that resulted in acceptance by the manufacturer and demonstrated a potential method of conducting better PCAs.

There is a common thread among all of these topics, which in itself is beyond the scope of this work, but without it there is great risk to the MBE process as a whole. This common task is model validation and it is absolutely critical to the success of MBE and MBSE. Once the model has been validated, a model management challenge arises that is equal in importance and a part of this work.

VALIDATION AND VERIFICATION

A detailed handling of verification and validation (V&V) is beyond the scope of this work, but it must at least be addressed as part of any MBE methodology. Structured blue light scanning (SBLS) is a technique of scanning hardware for developing solid models or comparing to existing solid models. While very useful in the world of reverse engineering, the context presented here is a method of validating solid models.

This is also the tool that enables model based PCAs combining CAD models with measured production hardware. This will be discussed further in a later section.

ANALYSIS WORKING GROUP

An analysis working group has been established and is in the process of developing a charter between the prime contractor and the US Government at this time. The intent is to grow the working group to all service stake holders.

There will always be a healthy tension between prime contractors and the USG in the area of analysis due to the expense and impact on schedules. In some cases the prime may apply engineering judgement they have gained through years of development and production. These views are not always seen in the same light by the USG, so the working group provides a forum to establish an acceptable position. Other examples are areas that are just hard to analyze or yet

other areas that can't be tested, so analysis provides the best risk mitigation increasing the importance of analytical methodology. This is also a potential avenue for information sharing when the contracts do not explicitly define models or results as deliverables. More mature systems, and especially those with an evolutionary history, truly benefit from such a working group.

NON-STANDARD LAUNCHER CASE STUDY FOR MODEL REUSE

A case study has been laid out to demonstrate the implementation of MagicDraw and the Windchill server using non-standard launchers. The same approach is planned to be applied to two new launcher developments scheduled to begin in FY19.

The non-standard launchers are derived from current production launchers based on requirements from low quantity users. The production four rail launcher is modified in accordance with work instructions and TDPs developed for each particular configuration. Examples of modifications include launcher electronics changed from AC input power to DC input power and rail retention force reduced from production levels to a user required level based upon the particular launching platform.

The plan is to pull the current production launcher performance specification into MagicDraw and create the SysML model adding parameters in requirements in areas where modifications are possible, such as retention force, input power type, etc. The intent is for the SE to be able to create a new specification by changing these parameters.

The plan for TDP management is to manage the CAD models while creating 2D drawings as needed. The first step in this process will be to scan the four rail production launcher using structured blue light scanning techniques. These scans will be used to validate the current four rail CAD model. Once the CAD model is validated, it will be loaded into Windchill to build configurations specific to the non-standard launchers. The challenge is to not interfere with the production hardware while maintaining these non-standard launchers. There are some non-standard parts that have been modified from production parts. These non-standard parts have been assigned new part numbers and there are appropriate callouts on the drawings defining how the modifications are to be made. The initial step will be to add the production part number to the non-standard part metadata in Windchill. This will be used to develop a query for checking the impact of production engineering change proposals (ECP) implemented on production parts. This is critical as the production part could possibly be changed though an ECP in a manner that prevents the non-standard part from being produced per the instruction on the non-standard drawing.

The next phase will be adding the analysis connectivity. For certain well bounded problems, it is anticipated that either equations or finite element models could be hyperlinked to the SysML parameters to allow the SE to generate the design data for altered requirements. Looking at the launch rail retention force as an example, it is based on compression springs. By defining the boundary conditions and other constraints, the SE could specify the new requirement for

retention force on the MagicDraw model and generate a new design with fabrication drawings. This would not be possible for every modification, but the more common changes that are seen would be addressed.

The overall plan is to implement this early in FY19 in sufficient time to adopt this approach for new launcher work. Implementation of this approach, requires validated CAD models and TDP if a 2D TDP is desired. Once the TDP is created, the drawings will update as the model is managed. One notable exception is the drawing notes and any references to specifications would still need to be managed manually for now. This will position the non-standard, and any new launchers for model based PCA.

MODEL BASED PHYSICAL CONFIGURATION AUDIT

The MBE coupled with structured blue light scanning is an enabler for model based PCA. One of the rocket pods managed by JAMS was scheduled for a PCA to be conducted at the vendor's fabrication facility. Although the launcher is fabricated from an old TDP, a CAD model had been developed by the AMRDEC Platform Integration Function. This model was developed for various integration and analytical tasks over the long production history of the launcher. The vendor agreed to support the investigation into a model based PCA allowing their hardware to be scanned using the structured blue light scanning methodology and compared to the AMRDEC solid model. The scanning for this investigation was also completed by the AMRDEC Platform Integration Function using GOM ATOS Professional inspection software and scanning hardware. As this was an investigation into the feasibility of this approach, the results are still being processed. One of the challenges has been discussed in an earlier section, which data set is true? The CAD model is a true representation of the EDIS managed 2D drawings, so when differences appear is it a hardware problem or drawing problem? The vendor was very supportive of this approach and even asked if they could get CAD models to pass down to their subcontractors. The conclusion of this particular effort is ongoing.

ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AMRDEC	Aviation and Missile Research, Development, and Engineering Center
ASME	American Society of Mechanical Engineering
CAD	Computer Aided Design
DC	Direct Current
ECP	Engineering Change Proposal
FVL	Future Vertical Lift

JAMS PO	Joint Attack Munition Systems Project Office
INCOSE	International Council on Systems Engineering
IPT	Integrated Product Team
MBE	Model Based Enterprise
MBSE	Model Based Systems Engineering
NIST	National Institute of Standards and Technology
NAFEMS	National Agency for Finite Element Methods and Standards
PCA	Physical Configuration Audit
SBLS	Structured Blue Light Scanning
SE	Systems Engineer
SMSWG	Systems Modeling and Simulation Working Group (Joint INCOSE-NAFEMS)
SysML	System Modeling Language
TDP	Technical Data Package
V&V	Verification and Validation

CONCLUSION

This task has resulted in the following accomplishments:

- The initial MagicDraw installation in JAMS PO, with subsequent training and additional installations.
- The initial Windchill installation for JAMS PO with workflows and MagicDraw integration planned.
- The initial use of structured blue scanning for CAD model validation in JAMS PO.
- The initial model based PCA experiment in JAMS PO.
- The establishment of an analysis working group between JAMS PO and their prime contractor.
- Development of a case study focused on MBSE MPTs for non-standard launchers with goal of transitioning results to new start launcher development.

- Membership in INCOSE-NAFEMS System Modeling and Simulation Working Group.
- Connections within the software industry to enable engineering analysis integration with MagicDraw SysML models.
- Connections within the software industry to integrate CAD model validation software with Windchill.

APPENDIX A: LIST OF PUBLICATIONS RESULTED

N/A

APPENDIX B: CITED AND RELATED REFERENCES

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