Air Force Institute of Technology

Develop America's Airmen Today ... for Tomorrow

U.S. AIR FORCE

STPA for Autonomy, Resilience, and MBSE

Presented at: MIT STAMP Workshop 2024

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AF Institute of Technology
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Aim High…Fly – Fight – Win

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Overview

Purpose:

- Highlight STAMP-STPA work at AFIT, generate discussions and future collaboration

Agenda:

- STPA for Autonomous Wingman Coordination Design
- STPA for Resilience in Space Architecture Development
- Current STPA Advancement
- STPA in Model-Based Systems Engineering

Future of Air Dominance

- **Fog of War**
  - Complex battle space
  - Autonomous platforms
  - Revolution in: Tactics, techniques, procedures

VENOM program: “the potential to **redefine air combat paradigms** by fostering novel **autonomous functions** for current and future crewed and uncrewed platforms,” said Maj. Ross Elder, VENOM developmental test lead

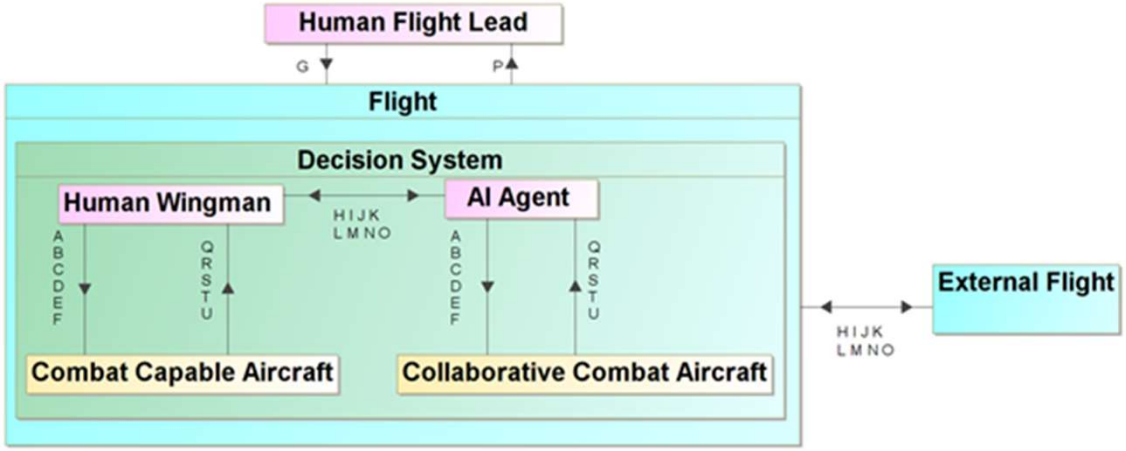
https://www.af.mil/News/Article-Display/Article/3728795/f-16s-arrive-to-be-modified-for-autonomous-testing/



Image in public domain. US Air Force

Future of Air Dominance

- **Elizabeth Pennington**
  - AFIT MS Thesis, Mar 2024
- **STPA**
  - Handles complexity
  - Uses abstraction
  - Focus – Beyond Visual Range Scenario
    - Launch missile
    - Decision to commit
  - Analysis of Coordination
    - STPA extension, STPA-Coordination (Johnson, 2017)



Control Actions	Coordination Details	Feedback
A: Communicate with Wingmen	H: Current/Adjusted Attack Plan	P: Compliance
B: Fly Formation/Profile	I: Select Targets	Q: Enemy Location/Status
C: Navigate	J: Abort? Y/N	R: Munition Status
D: Operate Sensors	K: Reattack? Y/N	S: A/C Health
E: Employ Countermeasures	L: Launch Timing	T: Location
F: Launch Missile	M: Communicate? Y/N	U: A/C Attitude
G: Commit	N: Determine Formation/Profile	
	O: Buddy Spike	

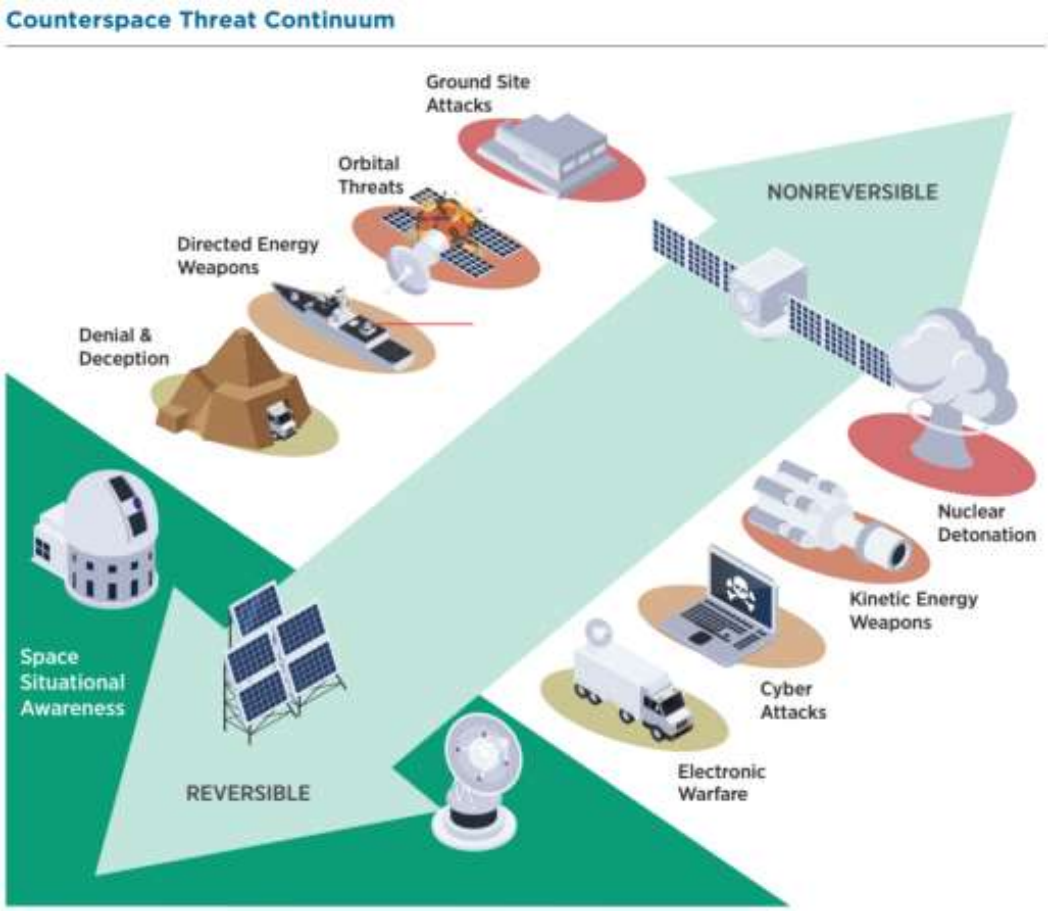
- **Results**
  - STPA framework for design
  - 290 Coordination loss scenarios/causal factors
  - 83 design considerations

(2024) Pennington, Elizabeth. A Model-Based and System Theoretic Approach to Design Advanced Autonomy for Air Dominance Missions: A Loyal Wingman Case Study. AFIT MS Thesis.

Resilient Space Architecture

- "We have got to **shift the space architecture**, if you will, from a handful of exquisite capabilities that are very hard to defend to a more robust, more **resilient architecture by design**." Gen. Raymond (2022)

- "there's no recipe and trying to come up with the analytical methods, the tools, the models…pressure on us to create something out of nothing." Space Warfighting Analysis Center director (2022)



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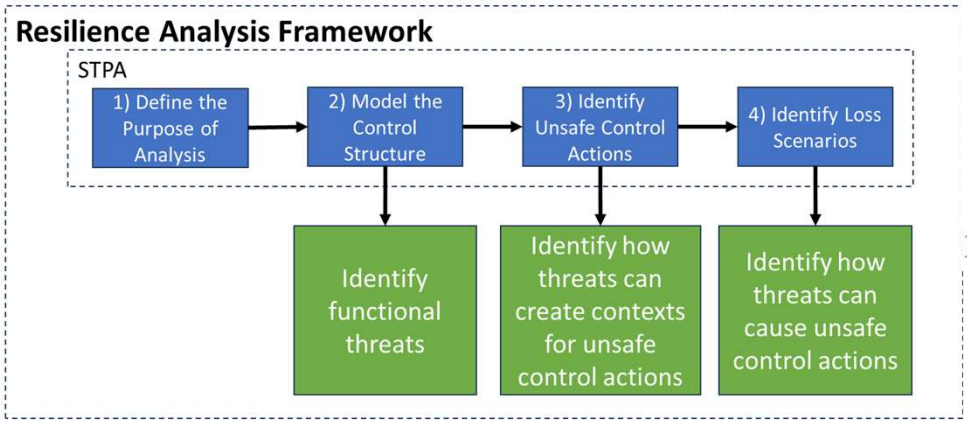
https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf

Resilient Space Architecture

- **Eric Sommer**
  - AFIT MS Thesis, Dec 2023
- **STPA**
  - A paradigm shift to assess resilience
  - Resilience ensured through system behavioral requirements, through design



- **Results**

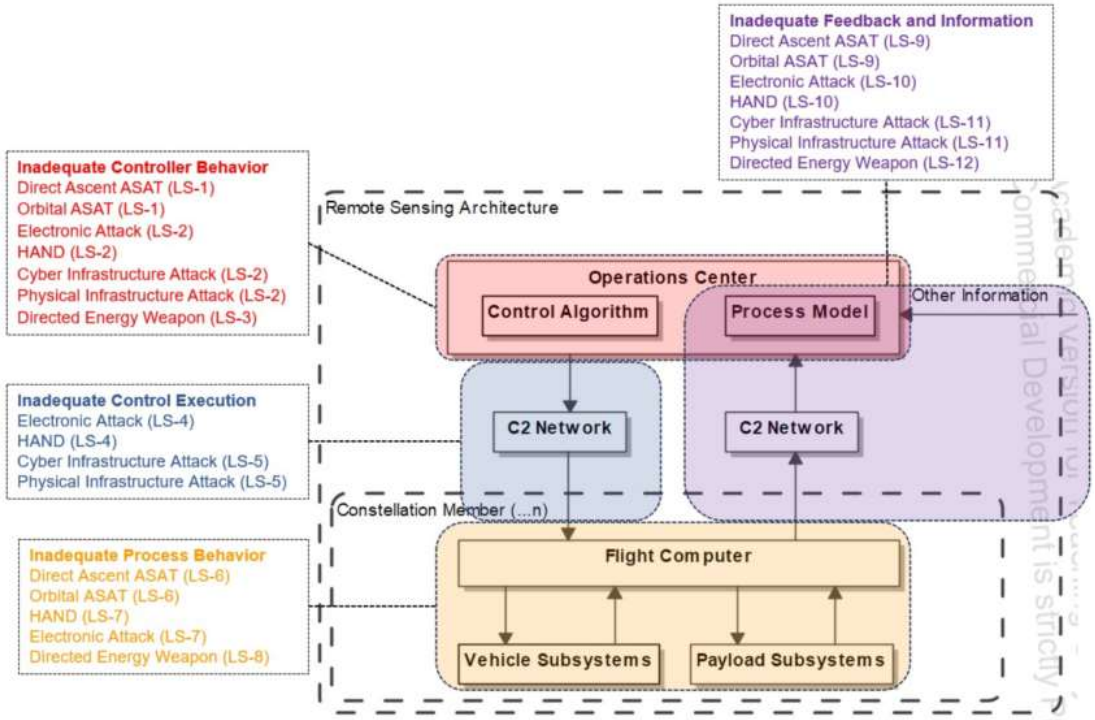


Figure 4. Threat Exploitation of the Remote Sensing Architecture Control Structure

(2023) Sommer, Eric. A System Theoretic Process Analysis Framework and Model Based Approach for Resilient Space Architecture Design. AFIT MS Thesis.

Current STPA Advancement

- **STPA for Preliminary & Critical Design Review Safety Requirements**
  - A small-UAS case study
  - Capturing the PDR to CDR transition
  - Model-based approach using SysML-RAAML for Technical Reviews

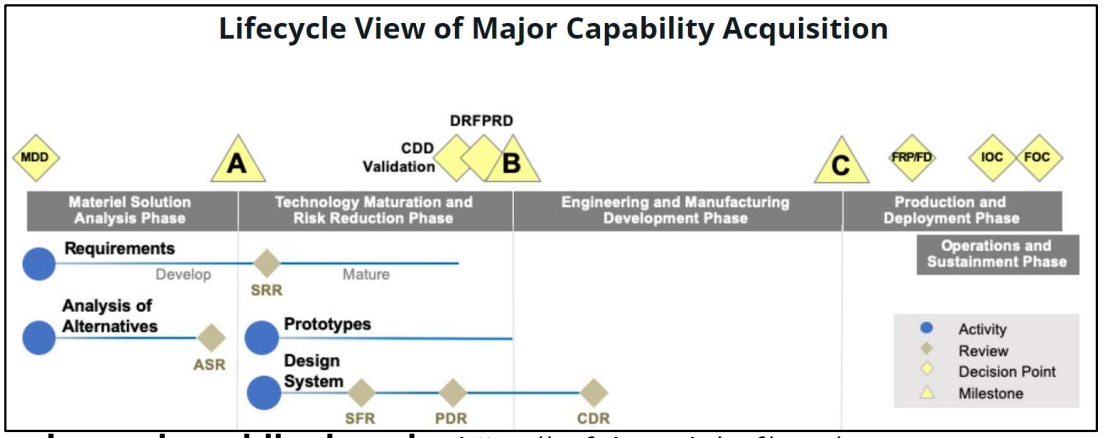
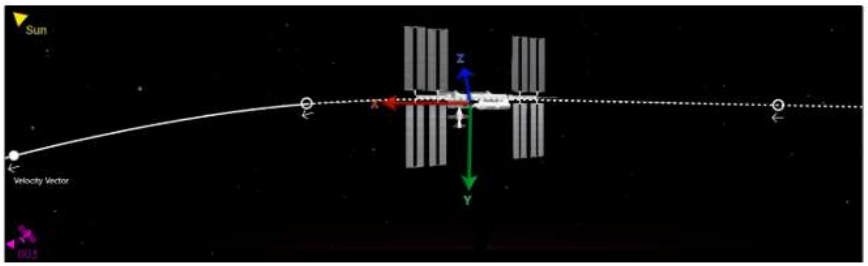


Image in public domain. https://aaf.dau.edu/aaf/mca/

- **STPA for STARS Architectural Analysis**
  - Safe Trusted Autonomy for Responsible Spacecraft
  - w/ AF Research Lab
  - Flexible human-autonomy teaming
  - STPA extended for Coordination

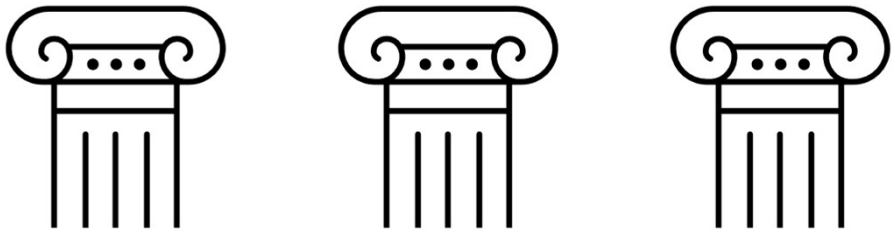


Concept design of the mission planning and operator's tool

Image in public domain.
https://afresearchlab.com/wp-content/uploads/2024/03/AFRL_STARS_FS_240318.1.pdf

STPA and MBSE

- **MBSE Framework** (Delligatti et al, 2014)



Language	Methods	Tools
SysML RAAML (Risk Analysis and Assessment Modeling Language)	***AFIT Research**	Catia

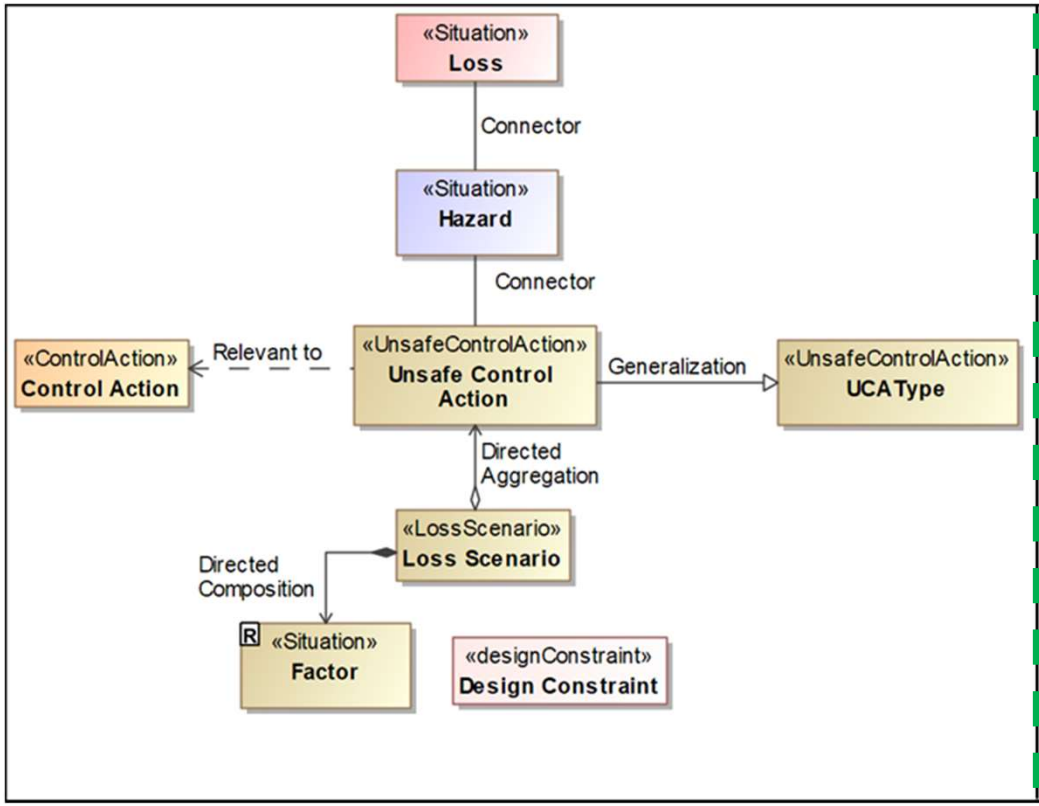
- **Why SysML, RAAML?**
  - perhaps the industry standard for MBSE
  - Support is at DOD level and down
  - Non-proprietary and open source specifications
  - Community influences standards

L. Delligatti, R. Steiner, and R. Soley, *SysML distilled: a brief guide to the systems modeling language*. Upper Saddle River, NJ Munich: Addison-Wesley, 2014.

STPA and MBSE

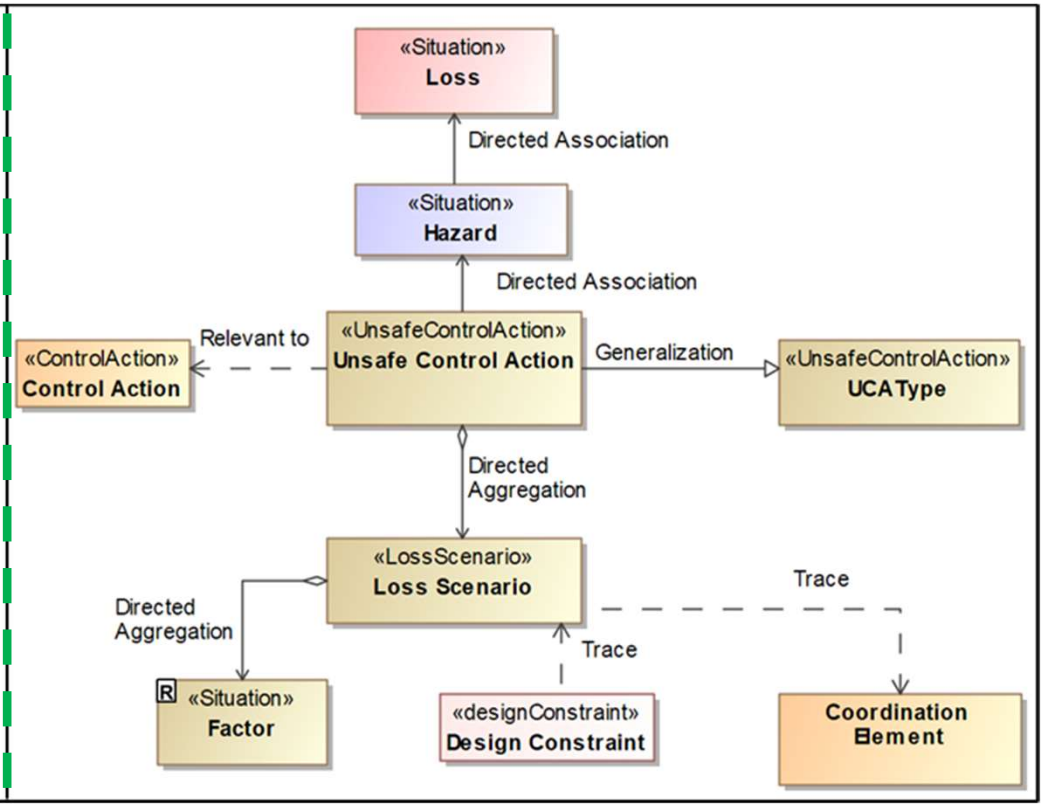
RAAML Baseline Relations

(2021) Object Management Group. Risk Analysis and Assessment Modeling Language Examples (Informative) (pp. 10–16). Object Management Group. https://www.omg.org/spec/RAAML/1.0/About-RAAML/



Recommended Relations

(2024) Pennington, Johnson, Colombi, Hobbs. *Integrating STPA Extended for Coordination into SysML Using RAAML*. (Accepted) 34th Annual INCOSE Int'l Symposium.*



*Brian Mar Best Student Paper Award

Questions?

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