



# System-Theoretic Process Analysis for Security (STPA-SEC): Cyber Security and STPA

William Young Jr, PhD

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# Disclaimer:

***The views expressed in this presentation are are those of the presenters and do not reflect the official policy or position of the United States Air Force, Department of Defense, Air Combat Command, MIT Lincoln Laboratory, Syracuse University, or the U.S. Government***



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# Overview of the Practice Session

**Session 2 (3:30 – 5:00): STPA-Sec Practice**

- **STPA-Sec for Security Engineering Analysis**
- **Concept Analysis**
- **Architectural Analysis**
- **Design Analysis**
- **User Q&A**
- **Summary and Conclusion**

**To Maximize the Available Time, I Will Assume Basic Familiarity With STAMP, STPA an Will Leverage John Thomas's Example from this Morning**



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# Rules of Engagement

- Extends aspects of Dr John Thomas's morning STPA tutorial
  - Won't cover the things he discussed
  - Will Identify security-related differences and additions
  - Will offer my techniques in a few areas
- Generally follows STPA Handbook guidelines
- Available time won't allow for deep dive, but will have time over the next two days to discuss and answer detailed questions
- This is notional example and greatly simplified to fit within the time allotted
- Brevity prevents replication of the group learning that normally occurs
- Can't simulate the iterative nature and the rich conversations that occur
- I want to save time at the end to address specific user questions encountered during real-world applications

**We are Summarizing 40+ Hours of Instruction into 90 Minutes…We Will Only Hit Wavetops**



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# STPA-Sec For Security Engineering Analysis

**Satellite System Example Based on John Thomas Example Used in Earlier STPA Tutorial (Used With Dr Thomas' Permission) and the Paper "A Top Down Approach for Eliciting Systems Security Requirements for a Notional Satellite System" by Mailoux, Span, Mills and Young**



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**Ends**

**Problem Framework – Concept Analysis**
- Goal / Purpose
- Unacceptable Losses
- Hazards
- High Level Constraints

→ Initial Security Requirements

Analysis / Synthesis
(Refine & Iterate)

**Ways**

**Intent**
**Increasing Detail**
**(Requirements)**

**Functional Framework – Architectural Analysis**
- Model Elements
- Responsibilities
- Functional Control Structure
- Control Actions
- Control Action Analysis Table (Step 1)

→ Security Constraints & Restraints

Analysis / Synthesis
(Refine & Iterate)

**Means**

**Enterprise Architecture – Design Analysis**
- Process Model Descriptions
- Process Model Variables (PMVs)
- PMV Values
- PMV Feedback
- Causal Scenarios (Adversary, Accident, Nature)
- War Gaming

→ Security Specifications


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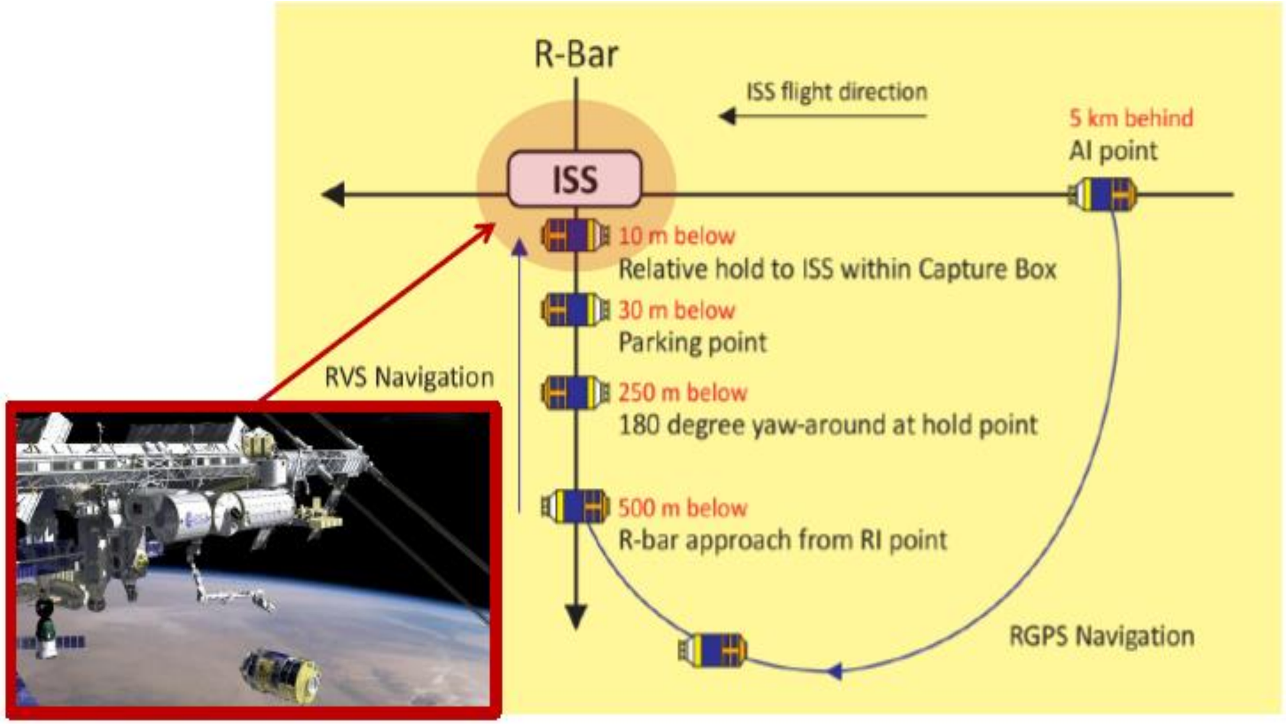
# Notional Spacecraft Through a Security Lens

<u>**From John Thomas' Example this Morning**</u>

- **Unmanned cargo transfer spacecraft**
- **Launched aboard rocket**
- **Rendezvous with International Space Station (ISS)**
- **Docks with ISS to deliver supplies**
- **Undocks and Returns to Earth**




<u>**Additional Factors**</u>

- **Proximity operations involve ISS (including crew), and ground stations**
- **Spacecraft employs proprietary software that company has invested significant IRAD to develop and patent**
- **System is commercially owned, operated, and maintained**
- **Company is liable for damage to supplies while enroute and for mission impact if supplies not delivered**

Additions to morning STPA Tutorial Scenario

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# Problem Framework: Concept Analysis

## Determining Initial Security Requirements



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# Concept Analysis Overview


| STPA-Sec Concept Analysis. | |
|---|---|
| **Step** | **Description** |
| **1. Define the System of Interest (SOI), SOI purpose and SOI goal*** | Capture the mission statement and key activities of the system:<br>1) A system to: (What)<br>2) By Means of: (How)<br>3) In Order to: (Why)<br>4) While: (Bounds) |
| **2. Identify unacceptable losses*** | Define high level, intolerable system outcomes to key stakeholders (e.g., loss of life, injury, damage to equipment, reputation, mission, etc.). |
| **3. Identify hazards** | Identify system states that when coupled with worst case conditions lead to an unacceptable loss. |
| **4. Develop system security constraints*** | Develop mission-informed security constraints that prevent the system from entering hazardous states. These constraints are synonymous with early safety, security, and resiliency functional requirements. |

* Security-related addition, modification, or technique



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# Big Picture: Synthesize (Frame) Security Problem


- **Sets the foundation for the security analysis**
- **Must ID all relevant stakeholders**
- **Must understand how product / service fits into organizational strategy**
- **Surface key assumptions (and dependencies)**
- **Satisfies key aspects of Business or Mission Analysis (BMA) in ISO/IEEE/IEC 15288**
- **Examine required functionality from a security perspective**

**“Many systems fail because their designers protect the wrong things, or protect the right things in the wrong way” – Ross Anderson in *Security Engineering***



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# Define System Purpose and Goal


**"A system to do {What = Purpose}**

**by means of {How = Method}**

**in order to contribute to {Why = Goals}**

**while {Constraints, Restraints}**

**Specify a gap between "as is" and "to be"**

**that will be addressed through a process (e.g. a transformation of some type)**

Sidebar

The Story of "Bob"

Military parallel is Operational Design (applied Operational Art) as captured in Joint Pub 5-0

**Iterative Process is Challenging, but Generates Rich Conversations in Practice (e.g. USAF MLV)**



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## <u>Format</u>

**"A system to do {What = Purpose}**

**by means of {How = Method}**

**in order to contribute to {Why = Goals}**

**while {constraints, restraints}**

**What Might Be a Possible Solution from the Spacecraft Example?**



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# Spacecraft Example


**"A system to do {What = Purpose}**

**by means of {How = Method}**

**in order to contribute to {Why = Goals}**

**while {constraints, restraints}"**


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# Spacecraft Example– Potential Solution


A system to **autonomously resupply ISS**

by means of **launching, navigating, docking, and undocking a space vehicle**

in order to **support the ongoing ISS mission and research** while **maintaining profitable operations, minimizing risk to ISS/cargo, and improving the company's position and branding as a responsible world leader in space technology .**

**This is one Solution, But There Others**



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# Adding Security-Related Unacceptable Losses


- **"Unacceptable Losses" and "Accidents" are the same thing**
- **Many of the security losses will overlap with safety accidents**
- **Security perspective may add nuance to a previous safety perspective**
- **Security perspective may also highlight important safety / security trades**
- **Focus on alternative "system" uses**
- **Focus on security concerns of non-traditional stakeholders**
- **Outcomes and final conditions, not failures**

**Simply Clarifying Unacceptable Losses May Provide a Significant Boost in Security Effectiveness!**



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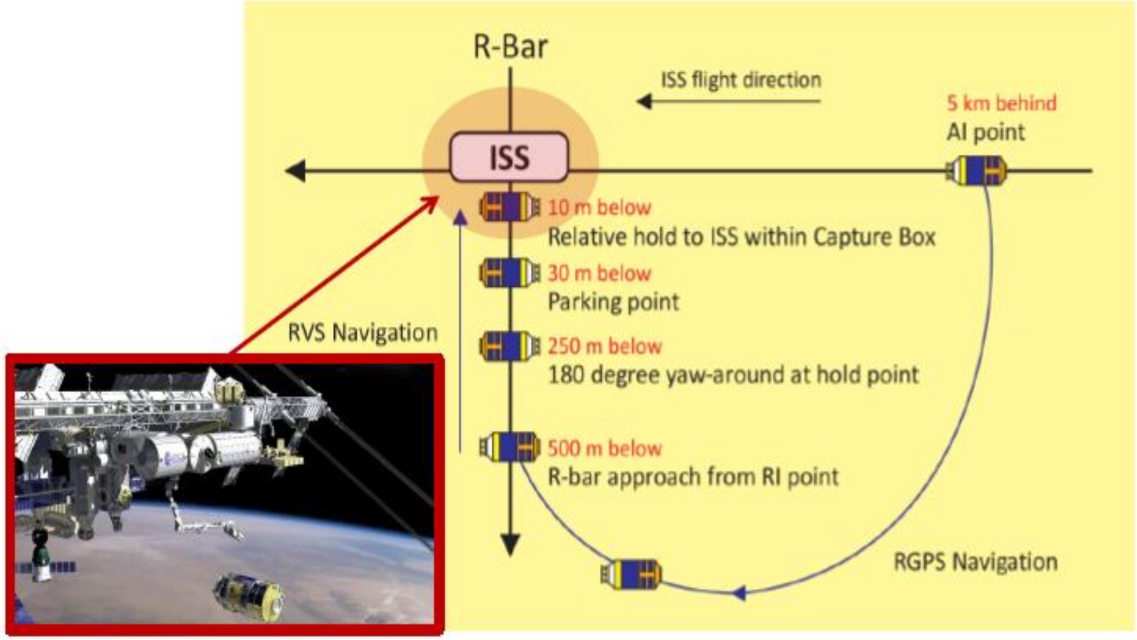
# Spacecraft Losses


- **Unacceptable Losses (From Earlier Today)**
- A-1: HTV collides with ISS
- A-2: Loss of delivery mission

- **Unacceptable Losses (Modified From Earlier Today)**
- L-1: Loss of Vehicle or ISS
- L-2: Significant Damage to ISS or Vehicle
- L-3: Loss of Resupply Payload

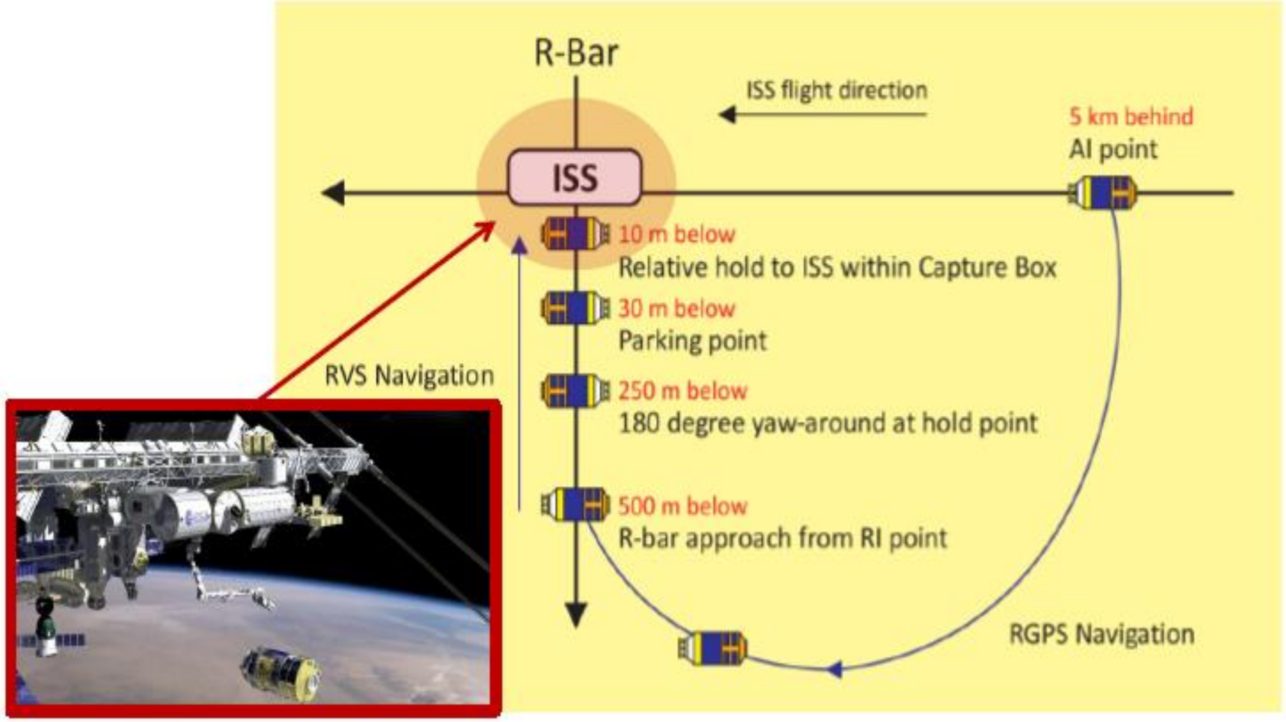



**Are these Safety or Security-Related Losses?**

# Spacecraft Unacceptable Losses


**Unacceptable Losses**

- L-1: Loss of Vehicle or ISS
- L-2: Significant Damage to ISS or Vehicle
- L-3: Loss of Resupply Payload




**Are there other unacceptable losses Related to Security? (Take a Few Minutes to Discuss)**



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# Expanded (Security-related) Spacecraft Unacceptable Losses


**Unacceptable Losses**

- L-1: Loss of Vehicle or ISS
- L-2: Significant Damage to ISS or Vehicle
- L-3: Loss of Resupply Payload
- **L-4: Loss of Reputation**
- **L-5: Loss of Intellectual Property**

A system to **autonomously resupply ISS**

by means of **launching, navigating, docking, and undocking a space vehicle**

in order to **support the ongoing ISS mission and research** while **maintaining profitable operations, minimizing risk to ISS/cargo, and improving the company's position and branding as a responsible world leader in space technology.**

**Are there other unacceptable losses Related to Security? (Take a Few Minutes to Discuss)**



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# Expanded Spacecraft Unacceptable Losses


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Tip: The "Why" and "While" provide insights to guide Unacceptable Losses

**Unacceptable Losses Are Traceable back to the Problem Statement**

# Using "How" Verbs to Help Identify System Level Hazards


| Losses / Verbs | Launch | Navigate | Dock | Undock |
|---|---|---|---|---|
| L1: Loss of Vehicle or ISS | | | | |
| L2: Significant Damage to ISS or Vehicle | | | | |
| L3: Loss of Resupply Payload | | | | |
| L4: Loss of Reputation | | | | |
| L5: Loss of Intellectual Property | | | | |

1 – High-level Functionality that is Required to Accomplish Goal

2 – Unacceptable Losses that Must be Avoided

Must Control "1" sufficiently to accomplish mission while not causing "2" (NOTE: This is true regardless of architecture!)



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# Using “How” Verbs to Help Identify System Level Hazards


| Losses \ Verbs | Launch | Navigate | Dock | Undock |
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| **L3: Loss of Resupply Payload** | | | | |
| **L4: Loss of Reputation** | | | | |
| **L5: Loss of Intellectual Property** | | | | |

We can use the *functional relationship* to gain insight into our Hazards (“A **condition with the potential** to cause injury, illness, or death of personnel; damage to or loss of equipment or property; or **mission degradation**.”[DoD])



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# Using “How” Verbs to Help Identify System Level Hazards


| Verbs / Losses | Launch | Navigate | Dock | Undock |
|---|---|---|---|---|
| L1: Loss of Vehicle or ISS | Improper launch functionality may place vehicle in unrecoverable orbit | Navigation to wrong point or at wrong time can lead to loss of vehicle | Excessive closure during docking can cause damage to ISS or ship | Inadvertent undocking may compromise vehicle or ISS |
| L2: Significant Damage to ISS or Vehicle | Excessive launch forces may damage vehicle or cargo | Navigation through space radiation fields may damage vehicle | Excessive closure during docking can cause damage to ISS or ship | Inadvertent undocking may compromise vehicle or ISS |
| L3: Loss of Resupply Payload | Excessive forces during launch may damage payload | Excessive forces on payload during enroute portion | Docking attempted when ISS not ready or docking functionality applied when not docking | Undocking functionality applied before desired |
| L4: Loss of Reputation | Failed launch attempt or vehicle destruction | Losing vehicle enroute | Vehicle colliding with ISS when under control of company | Vehicle undocking with ISS when commanded |
| L5: Loss of Intellectual Property | Monitored telemetry may reveal proprietary data | Monitored telemetry may reveal proprietary data | Monitored telemetry may reveal proprietary data | Monitored telemetry may reveal proprietary data |

# Using "How" Verbs to Help Identify System Level Hazards


| Verbs / Losses | Launch | Navigate | Dock | Undock |
|---|---|---|---|---|
| L1: Loss of Vehicle or ISS | Improper launch functionality may place vehicle in unrecoverable orbit | Navigation to wrong point or at wrong time can lead to loss of vehicle | Excessive closure during docking can cause damage to ISS or ship | Inadvertent undocking may compromise vehicle or ISS |
| L2: Significant Damage to ISS or Vehicle | Excessive launch forces may damage vehicle or cargo | Navigation through space radiation fields may damage vehicle | Excessive closure during docking can cause damage to ISS or ship | Inadvertent undocking may compromise vehicle or ISS |
| L3: Loss of Resupply Payload | Excessive for… launch ma… payload | | …when … g | Undocking functionality applied before desired |
| L4: Loss of Reputation | Failed launch … or vehicle destruction | | …n ISS … control of company | Vehicle undocking with ISS when commanded |
| L5: Loss of Intellectual Property | **Monitored telemetry may reveal proprietary data** | **Monitored telemetry may reveal proprietary data** | **Monitored telemetry may reveal proprietary data** | **Monitored telemetry may reveal proprietary data** |

Telemetry must be provided for remote operations. But it may also potentially disclose propriety data

# Using "How" Verbs to Help Identify System Level Hazards


| Verbs / Losses | Launch | Navigate | Dock | Undock |
|---|---|---|---|---|
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| L5: Loss of Intellectual Property | Monitored telemetry may reveal proprietary data | Monitored telemetry may reveal proprietary data | telemetry may reveal proprietary data | Monitored telemetry may reveal proprietary data |

Docking Maneuver (e.g. thrust) must be constrained within limits while vehicle is in close proximity to ISS

# Identifying a Missing Verb


| Losses \ Verbs | Launch | Navigate | Dock | Undock |
|---|---|---|---|---|
| L1: Loss of Vehicle or ISS | Improper launch functionality may place vehicle in unrecoverable o... | Navigation to wrong point or at wrong time... | Excessive closure during docking can cause damage... | Inadvertent undocking may compromise vehicle or ISS |
| L2: Significant Damage to ISS or Vehicle | Excessiv... may... ca... | | | ...tent ...may |
| L3: Loss of Resupply Payload | ...pa... | | | ...y ...ore ...ed |
| L4: Loss of Reputation | Failed lau... or vehicle destru... | | | ...le undocking with ISS when commanded |
| L5: Loss of Intellectual Property | Monitored telemetry may reveal proprietary data | Monitored telemetry may reveal proprietary data | Monitored telemetry may reveal proprietary data | Monitored telemetry may reveal proprietary data |

We can also use the matrix to help ID previously missed functionality

# Identifying a Missing Verb


| Losses \ Verbs | Launch | Navigate | Dock | Undock | Maintain (environment) |
|---|---|---|---|---|---|
| L1: Loss of Vehicle or ISS | | | | | |
| L2: Significant Damage to ISS or Vehicle | | | | | |
| **L3: Loss of Resupply Payload** | | | | | |
| L4: Loss of Reputation | | | | | |
| L5: Loss of Intellectual Property | | | | | |

L3 Highlights functionality that is required to achieve the goal and has an associated unacceptable loss, but no associated verb

# Hazards

| Hazard | Description | Worst Case Environment | Associated Losses |
|---|---|---|---|
| **H2:** Safe Closure Rate Between Space Vehicle and ISS exceeded | Commanded or uncommanded thrust provided in close proximity to ISS that takes vehicle out of safe closure parameters | ISS Crew or GSS crew does not detect deviation and/or is unable to take corrective actions to prevent a collision | L1, L2 , L3 |


**What system state or set of conditions together with a set of worst-case environmental conditions will lead to a loss? (Just like this Morning's STPA Tutorial)**



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# Hazards to Losses Cross Walk


| | | Losses | | | | |
|---|---|---|---|---|---|---|
| | | L1: Loss of Vehicle or ISS | L-2: Significant Damage to ISS or Vehicle | L-3: Loss of Resupply Payload | L-4: Loss of Reputation | L-5: Loss of Intellectual Property |
| Hazards | **H1:** H1: Failure to Maintain Safe Separation between the Space Vehicle and the ISS | X | X | X | X | |
| | **H2:** Exceed Safe Closure Rate Between Space Vehicle and ISS | X | X | X | | |
| | **H3**: Payload Environment not Maintained Within Operational Limits | | | X | | |
| | **H4**: Launch parameter limits exceeded | X | X | X | | |
| | **H5**: Proprietary data disclosed to unauthorized entity | | | | X | X |

# Develop High-level System Security Constraints


| Hazard | System Constraint |
|---|---|
| **H1:** H1: Failure to Maintain Safe Separation between the Space Vehicle and the ISS | |
| **H2:** Exceed Safe Closure Rate Between Space Vehicle and ISS | C2: System must maintain safe closure rate with ISS during docking and undocking |
| **H3**: Payload Environment not Maintained Within Operational Limits | |
| **H4**: Launch parameter limits exceeded | |
| **H5**: Proprietary data disclosed to unauthorized entity | |

**We Will Leverage ABORT functionality to Enforce this Constraint**



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# Functional Framework: Architectural Analysis

## Developing Security Constraints and Restraints



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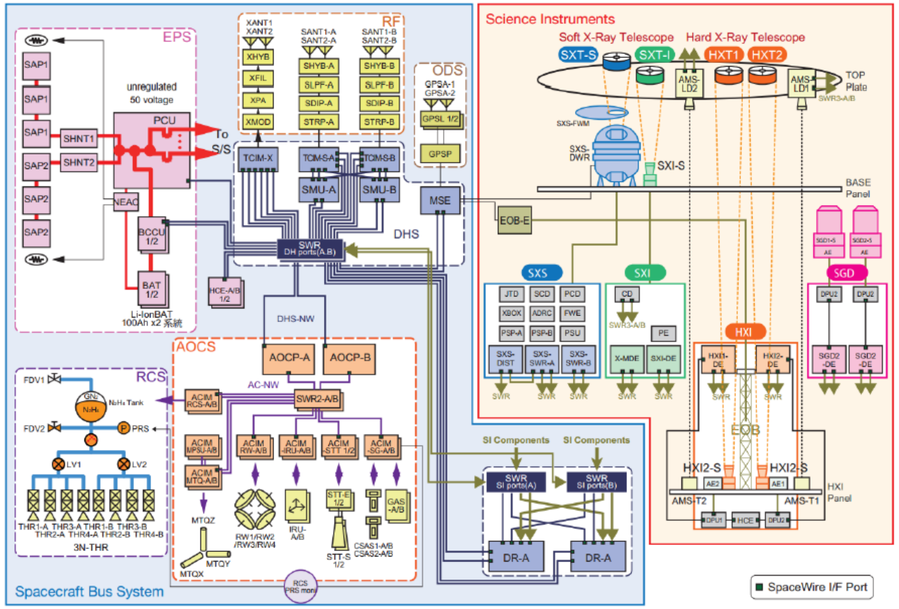
# Spacecraft Example– Architectural Analysis Overview

**Need Functional Equivalent**



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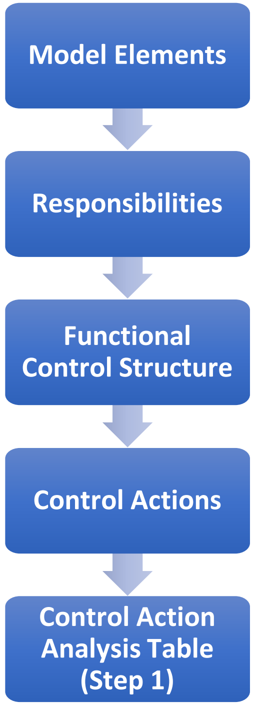
# Architectural Analysis Overview




| STPA-SEC ARCHITECTURAL ANALYSIS. | |
|---|---|
| **Step** | **Description** |
| **1. Identify model elements** | Identify actor(s), controller(s), and controlled process(es) for the SoI at the desired level of abstraction. |
| **2. Identify each  elements’ responsibilities** | Capture the description and actions planned to be taken for the model elements identified. |
| **3. Build Initial Functional Control Structure to Model control relationships** | Organize the model elements to pictorial show the relationships between elements in a functional control structure. |
| **4. Identify Control Actions (CA)** | Captures (in verb form) the actions necessary for each element to execute their responsibilities. |
| **5. Complete the CA analysis table** | The CA analysis table systematically enumerates which hazards are caused by each CA identified in step 4. |



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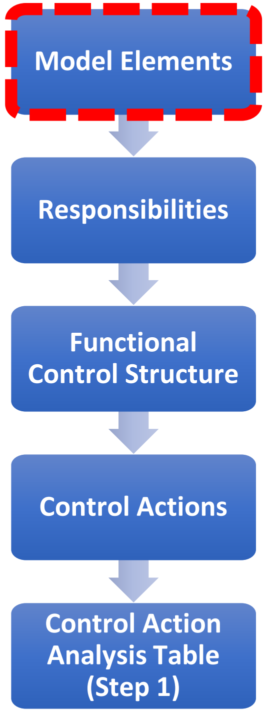
# Spacecraft– Model Elements




## Problem Space (Function)

A system to **autonomously resupply ISS**

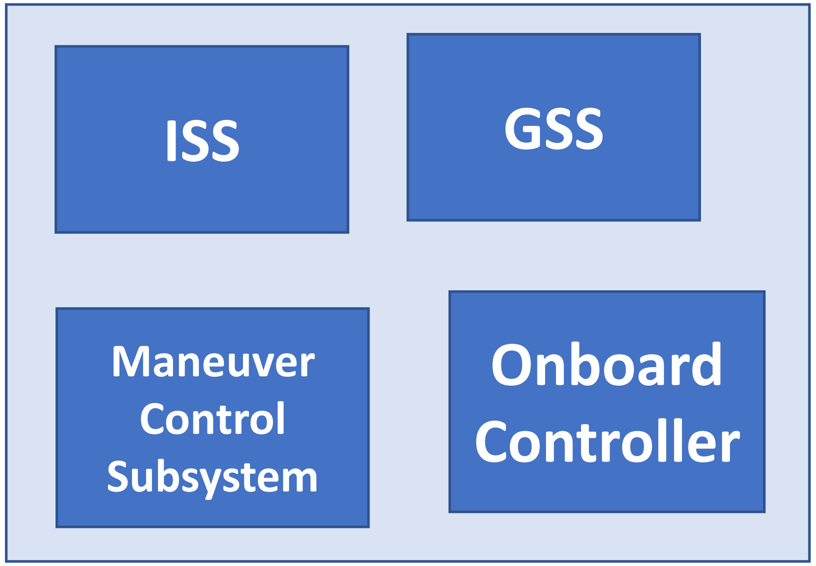
by means of **launching, navigating, docking, and undocking a space vehicle and maintaining cargo**

in order to **support the ongoing ISS mission and research**

while **preserving payload, maintaining cost effective operations, minimizing risk to the astronauts, and improving the organization's position and branding as a responsible community partner and world leader in technology .**

Developed in Initial Problem Framing

## Solution Space (Form)




Entities are Specified and Implied in Initial Documentation (But must Parse)

# Spacecraft– Model Elements

- **Model Elements**
- Responsibilities
- Functional Control Structure
- Control Actions
- Control Action Analysis Table (Step 1)

A system to **autonomously resupply ISS**

by means of **launching, navigating, docking, and undocking a space vehicle** **and maintaining cargo**

in order to **support the ongoing ISS mission and research**

while **preserving payloa... taining cost effective operations, minimizing risk to the a... uts, and improving the organization's position and branding ... sponsible community partner and ... der in technology .**

| High-Lev Functio Act | Model Elemen | Descriptio |
|---|---|---|
| | | |

**Architectural Sketches (e.g. DoDAF)**

**INITIAL CAPABILITIES DOCUMENT**

**Our Example Problem will focus on analyzing the statement: "System will be capable of ABORTING docking maneuver if unsafe conditions arise"**

# Entity Activity Diagram

| Verbs / Entity | Launch | Navigate | Dock | Undock | Maintain (environment) |
|---|---|---|---|---|---|
| ISS Segment | | | | | |
| GSS Segment | | | | | |
| Onboard Vehicle Control System | | | | | |
| Maneuver Subsystem | | | | | |
| Environmental control subsystem | | | | | |
| Other Subsystems | | | | | |

Identify data (Parse) documents and place specified and implied responsibilities for the entities inside the various boxes

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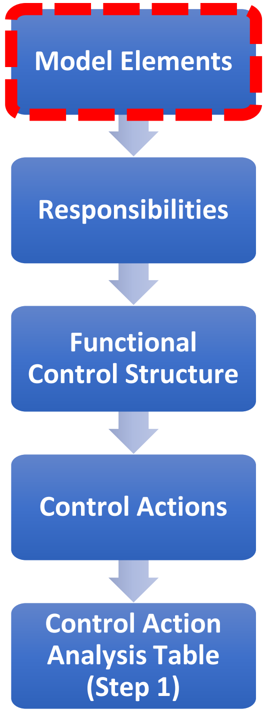
# Spacecraft– Model Elements




| High-Level Functional Activity | Model Elements | Description |
|---|---|---|
| **Dock** | ISS | ISS be capable of commanding an ABORT if unsafe conditions arise during docking |
| **Dock** | GSS | GSS be capable of commanding an ABORT if unsafe conditions arise during docking |
| **Dock** | Onboard Control System | **?** |

**Do we Expect the Spacecraft to be capable of internally (OCS) directed ABORT? (Implied Functionality ?)**



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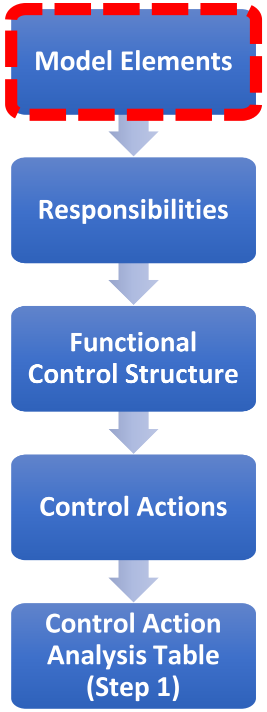
# Spacecraft– Model Elements




| High-Level Functional Activity | Model Elements | Description |
|---|---|---|
| **Dock** | ISS | GSS be capable of commanding an ABORT if unsafe conditions arise during docking |
| **Dock** | GSS | GSS be capable of commanding an ABORT if unsafe conditions arise during docking |
| **Dock** | Onboard Control System | **OCS** receive (encrypted) ABORT when issued by ISS or GSS, decrypt (if required), terminate unsafe maneuver, command Attitude Control System to return vehicle to a safe distance from ISS and safe operational parameters. OCS will be capable of automatically sensing and commanding the Attitude Control System to ABORT docking maneuver if unsafe conditions arise during docking |



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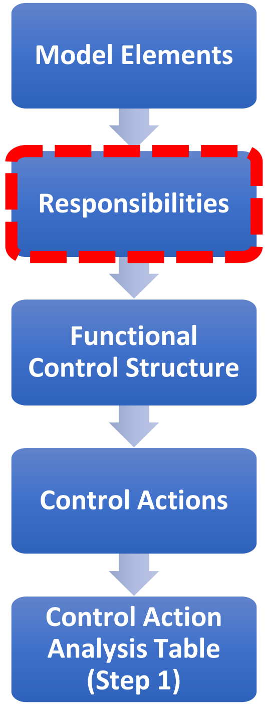
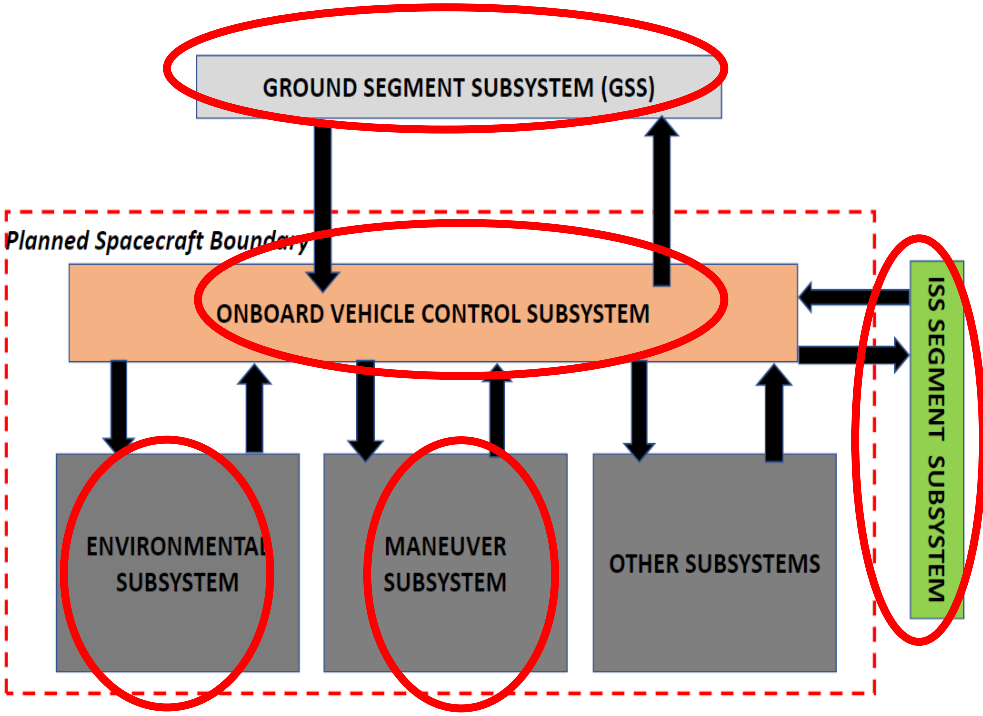
# Spacecraft– Responsibilities

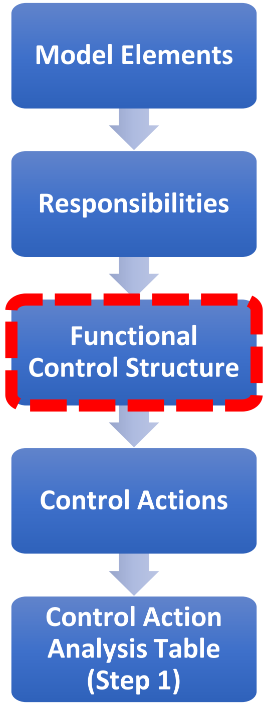


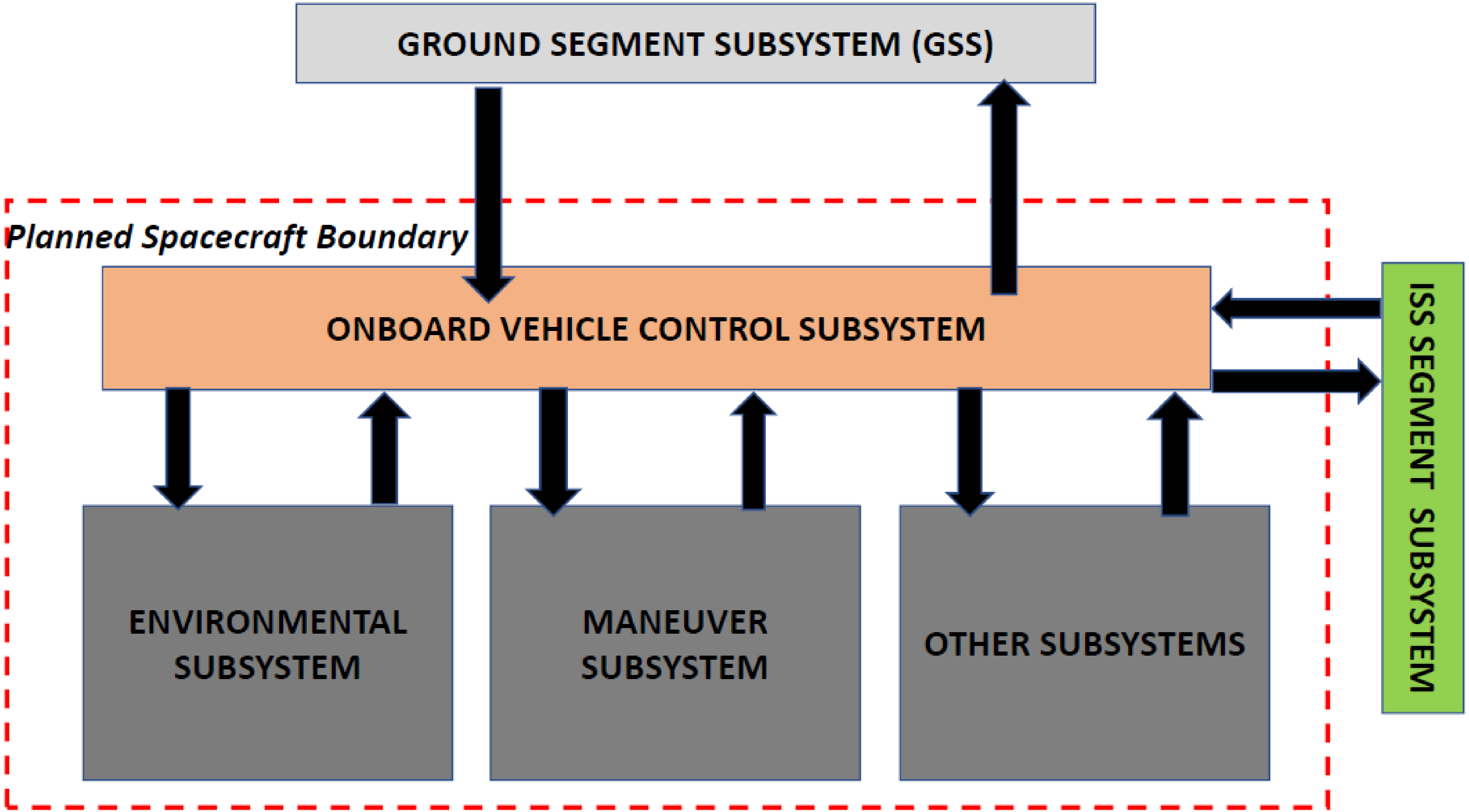

**Key Activity: Docking**

| Element | Responsibility Description |
|---|---|
| Ground Segment | • Initiate process<br>• Send ABORT signal (encrypt?)<br>• Monitor progress |
| ISS Segment | • Monitor progress<br>• Manually Intervene if required |
| Onboard Control System | • Receive ABORT signal<br>• Command ABORT to ACS<br>• Command ABORT if required and not otherwise commanded<br>• Decrypt? |
| Maneuver Subsystem | |
| Environmental Subsystem | |



# Spacecraft– Control Structure



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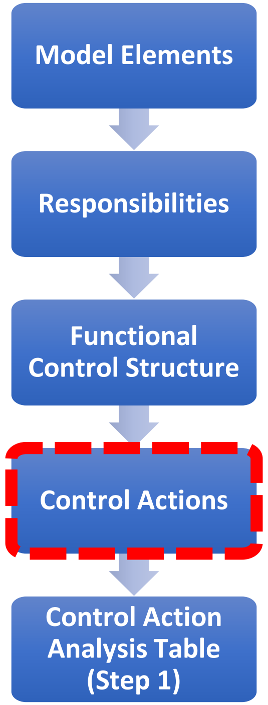
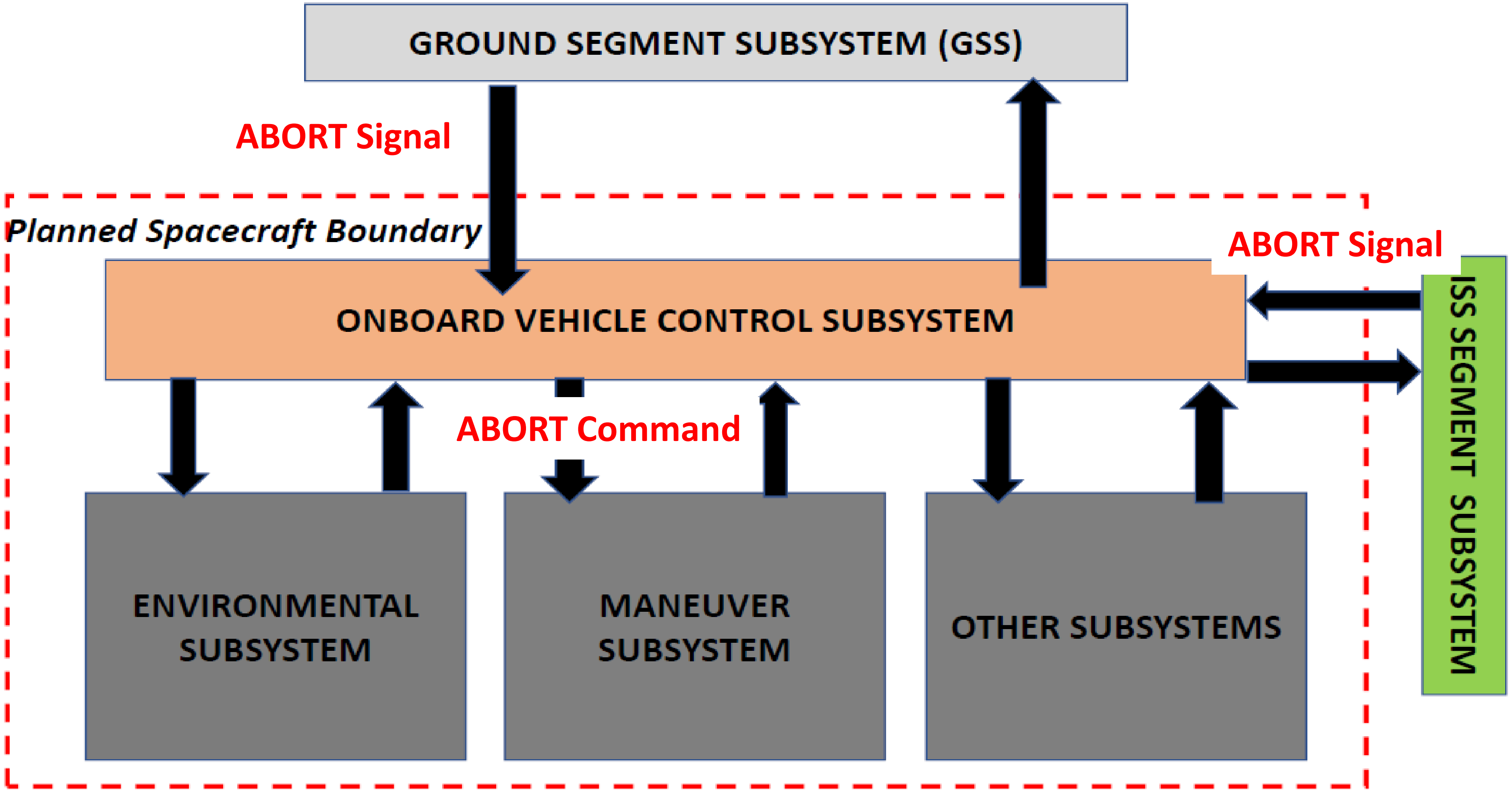
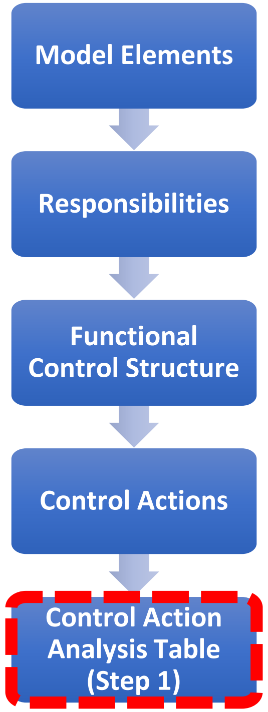
# Spacecraft– HCAs (Unsafe / Unsecure)




HCA - Hazardous Control Action

# Spacecraft– HCAs (Unsafe / Unsecure)




| Control Action | Not providing causes hazard | Providing causes hazard | Incorrect Timing or Order | Stopped too soon or applied too long |
|---|---|---|---|---|
| CA1: ABORT | OCS not providing ABORT command is hazardous when spacecraft closure is outside planned parameters in close proximity to ISS [H-1, H-2] | OCS providing ABORT command is hazardous when command places vehicle outside safe operating envelope [H-1, H-2] | OCS providing ABORT command too late is hazardous when corrective measures allow insufficient time to prevent collision [ H-1, H-2] | OCS providing ABORT command for too short a period is hazardous when corrections are not applied long enough to prevent collision [ H-1, H-2] |

HCA - Hazardous Control Action

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# Enterprise Architecture: Design Analysis

**Establishing Initial Security Specifications**



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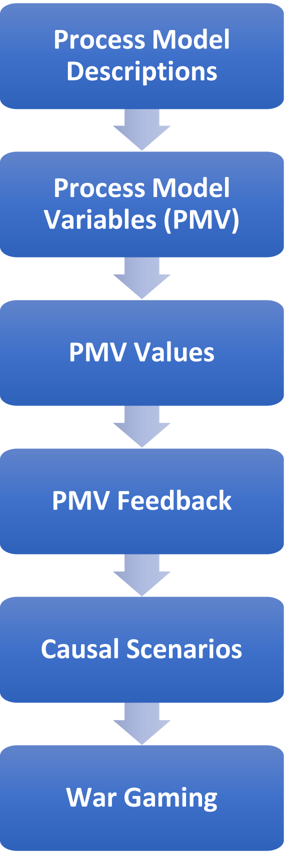
# Design Analysis Overview




**STPA-SEC DESIGN ANALYSIS.**

| Step | Description |
|---|---|
| **1. Develop process model descriptions** | Describes the decision logic ("in plain English") for executing a given CA. |
| **2. Identify Process Model Variables (PMV)** | PMVs are measurable indicators of the conditions that trigger a CA. |
| **3. Specify PMV values** | PMV values are all the possible values a PMV can be assigned both acceptable and hazardous. |
| **4. Identify PMV sensors** | Identifies which sensors provide PMV values to the actors and controller for decision making. |
| **5. Develop causal scenarios** | Brainstorm how a specific implementation of the system may be compromised. Identifies critical CAs and validates the thoroughness of the model, CAs, and constraints. |



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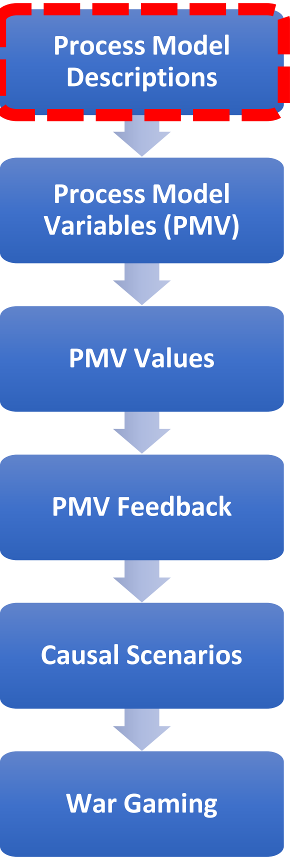
# Developing Process Model Descriptions




| Element: Onboard Control System | | |
|---|---|---|
| **Responsibilities**: Receive (encrypted) ABORT when issued by ISS or GSS, decrypt (if required), terminate unsafe maneuver, command Attitude Control System to return vehicle to a safe distance from ISS and safe operational parameters. OCS will be capable of automatically sensing and commanding the Attitude Control System to ABORT docking maneuver if unsafe conditions arise | | |
| **Control Actions** | **Key Activity** | **Process Model Description / Decision Logic** |
| ABORT | Docking | Issue ABORT Signal when___{context}___ |
| | | Issue ABORT Signal when___{context}___ |
| | | Issue ABORT Signal when___{context}___ |



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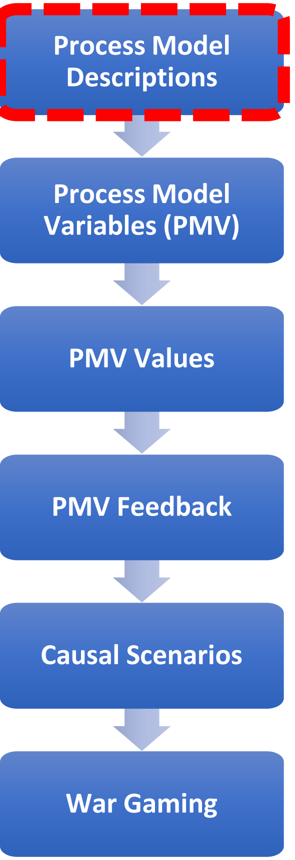
# Developing Process Model Descriptions




**Element: Onboard Control System**

**Responsibilities**: Receive (encrypted) ABORT when issued by ISS or GSS, decrypt (if required), terminate unsafe maneuver, command Attitude Control System to return vehicle to a safe distance from ISS and safe operational parameters. OCS will be capable of automatically sensing and commanding the Attitude Control System to ABORT docking maneuver if unsafe conditions arise

| Control Actions | Key Activity | Process Model Description / Decision Logic |
|---|---|---|
| ABORT | Docking | Issue ABORT when *ABORT SIGNAL RECEIVED FROM GSS* and Vehicle is X Distance from ISS |
| | | Issue ABORT when *ABORT SIGNAL RECEIVED FROM ISS* and Vehicle is X Distance from ISS |
| | | Issue ABORT Signal when *UNSAFE MANEUVER SENSED* and Vehicle is X Distance from ISS |



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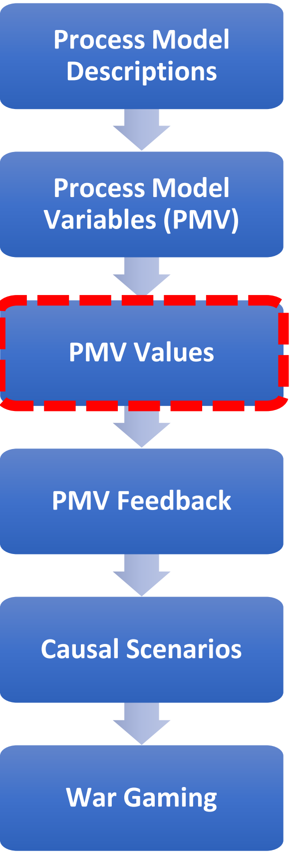
# Identify Process Model Variables

- Process Model Descriptions
- **Process Model Variables (PMV)**
- PMV Values
- PMV Feedback
- Causal Scenarios
- War Gaming

| Element: Onboard Control System | | | |
|---|---|---|---|
| Responsibilities: Receive (encrypted) ABORT when issued by ISS or GSS, decrypt (if required), terminate unsafe maneuver, command Attitude Control System to return vehicle to a safe distance from ISS and safe operational parameters. OCS will be capable of automatically sensing and commanding the Attitude Control System to ABORT docking maneuver if unsafe conditions arise | | | |
| Control Actions | Key Activity | Process Model Description / Decision Logic | Process Model Variables |
| ABORT | Docking | Issue ABORT when *ABORT SIGNAL RECEIVED FROM GSS* and Vehicle is X Distance from ISS | 1) ABORT Signal Received from GSS<br>2) Distance from ISS |
| | | Issue ABORT when *ABORT SIGNAL RECEIVED FROM ISS* and Vehicle is X Distance from ISS | 1) ABORT Signal Received from ISS<br>2) Distance from ISS |
| | | Issue ABORT when *UNSAFE MANEUVER SENSED* and Vehicle is X Distance from ISS | 1) Unsafe Maneuver Sensed<br>2) Distance from ISS |

# Specify Process Model Variable Values




- ABORT Signal Received From GSS
  - Yes
  - No
  - Unknown
- ABORT Signal Received From ISS
  - Yes
  - No
  - Unknown
- Unsafe Maneuver Sensed
  - Match
  - Mismatch
  - Unknown
- Distance from ISS
  - Close
  - Not Close
  - Unknown

**How Should We Initially Specify the Values for "Distance to ISS"?**



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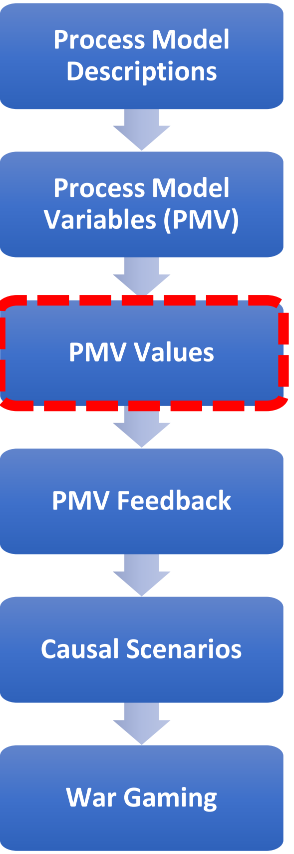
# Specify Process Model Variable Values




| Issue ABORT (YES / NO) | ABORT Rec'd from GSS | | | ABORT Rec'd from ISS | | | UNSAFE Maneuver Sensed | | | Distance from ISS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Unk | Yes | No | Unk | Mat | Mis | Unk | Close | Not Close | Unk |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

Complete Context Table (Truth Table for Potential Contexts)

Can Now Define When Onboard Control System Must and Must Not Invoke ABORT functionality

**Entire Context Table Can Be Captured in Leveson's SpecTRM-RL Tables**



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# Specify Process Model Variable Values

- Process Model Descriptions
- Process Model Variables (PMV)
- PMV Values
- PMV Feedback
- Causal Scenarios
- War Gaming

| Issue ABORT (YES / NO) | ABORT Rec'd from GSS | | | ABORT Rec'd from ISS | | | UNSAFE Maneuver Sensed | | | Distance from ISS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Unk | Yes | No | Unk | Mat | Mis | Unk | Close | Not Close | Unk |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

Complete Context Table (Truth Table for Potential Contexts)

Can Now Define When Onboard Control System Must and Must Not Invoke ABORT functionality

**SpecTRM-RL Tables are Testable Software Specifications**



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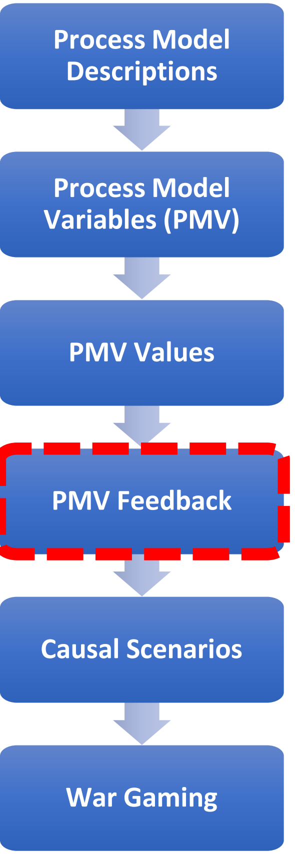
# Identify Process Model Variable Sensor Feedback




- **Establish required feedback for each PMV**
- **How will each value be determined?**
  - **ABORT Command Received From GSS, ISS**
  - **Distance from ISS**
  - **Unsafe maneuver sensed**
- **Easily catch missing feedback in documents**



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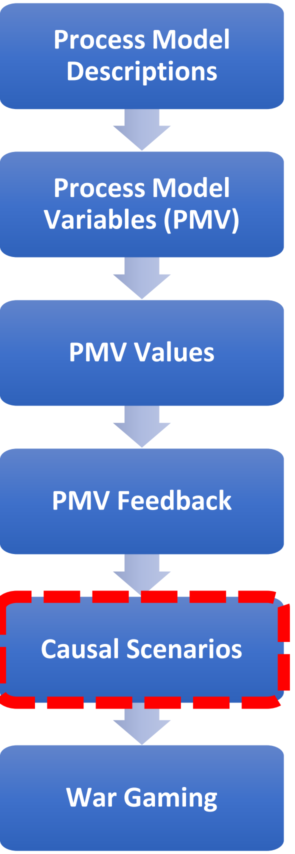
# Identifying Scenarios that Lead to Hazardous Control Actions




- **Scenarios should be used to facilitate deeper insights and understanding, they are not a checklist**
- **Scenarios provide an opportunity to engage technical experts and ask key questions necessary to support improved requirements**
- **Scenarios form a connected narrative to understand and explain interactions across the system (and set appropriate requirements)**
- **Scenarios should provide useful insight or generate additional questions for deeper debate and discussion**
  - **Scenarios such as "denial of service attack prevents controller from issuing ABORT command" aren't really as useful as "controller doesn't issues ABORT command when vehicle exceeds safe closure rate because ISS and GSS disagreed on need to ABORT."**



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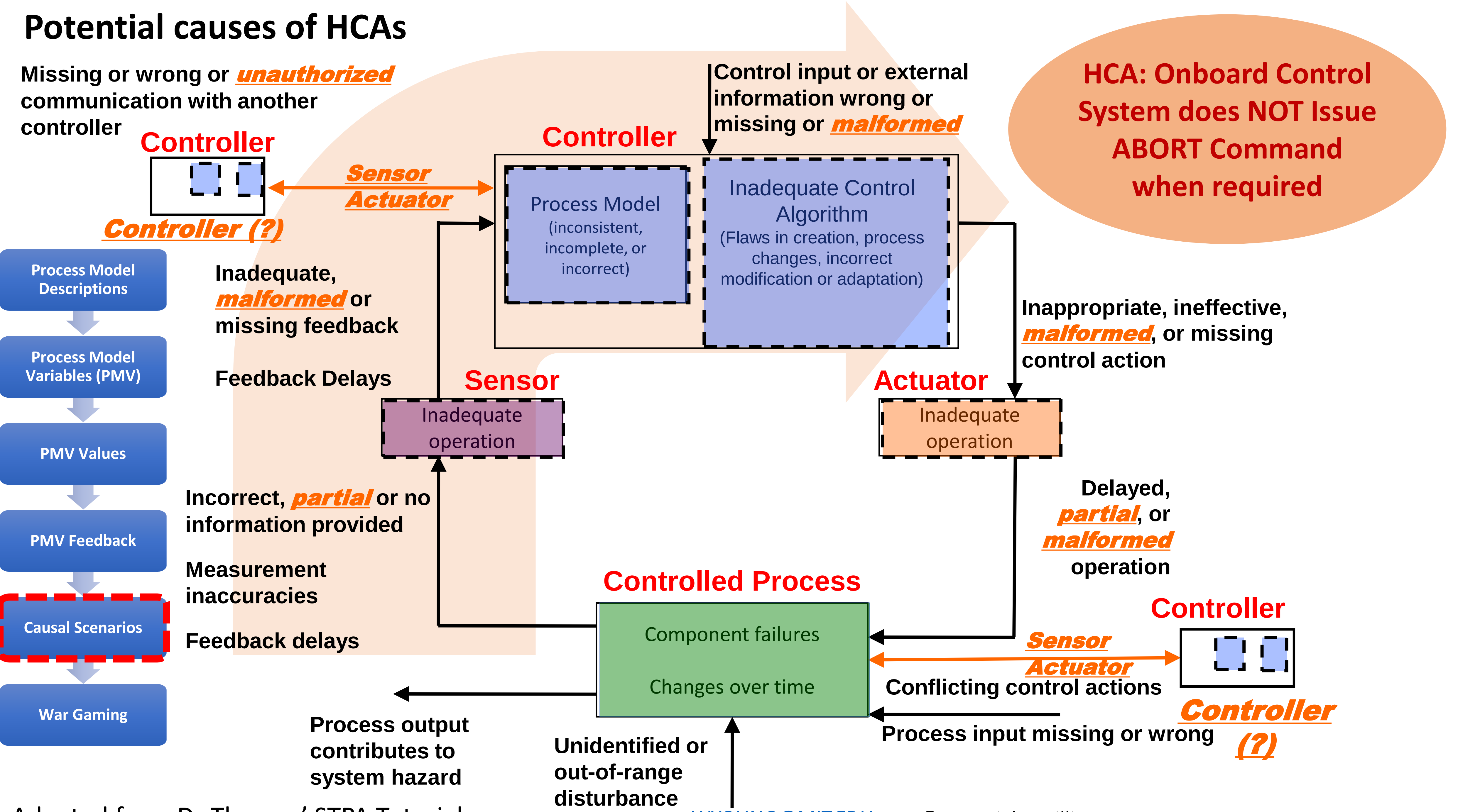
# Potential causes of HCAs



# Scenario Discussion

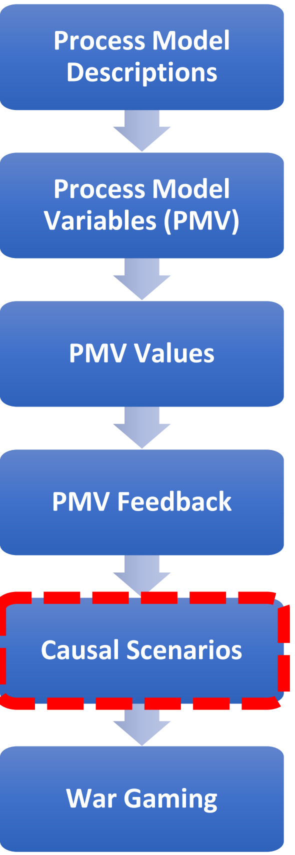
- Process Model Descriptions
- Process Model Variables (PMV)
- PMV Values
- PMV Feedback
- Causal Scenarios
- War Gaming

| HCA: Onboard Control System (OCS) Does Not Command ABORT to Maneuver Subsytem after receiving ABORT signal from ISS and in close proximity BECAUSE ____SCENARIO____ | | |
|---|---|---|
| **Scenario** | Associated Causal Factors | Rationale/Notes |
| **GSS did not issue or confirm the command.** | | |



Adapted from Dr Thomas' STPA Tutorial William.Young.3@US.AF.Mil

# Scenario Discussion




**HCA: Onboard Control System (OCS) Does Not Command ABORT to Maneuver Subsytem after receiving ABORT signal from ISS and in close proximity BECAUSE _____SCENARIO_____**

| Scenario | Associated Causal Factors | Rationale/Notes |
|---|---|---|
| GSS did not issue or confirm the command. | •Malformed signal from GSS<br>•Partial signal from GSS<br>•Missing signal from GSS<br>•Inconsistent process model | Malicious logic on OCS reports false/delayed/malformed information.<br><br>Malicious logic on computer modifies process model variable to indicate that ISS is NOT in close proximity. |



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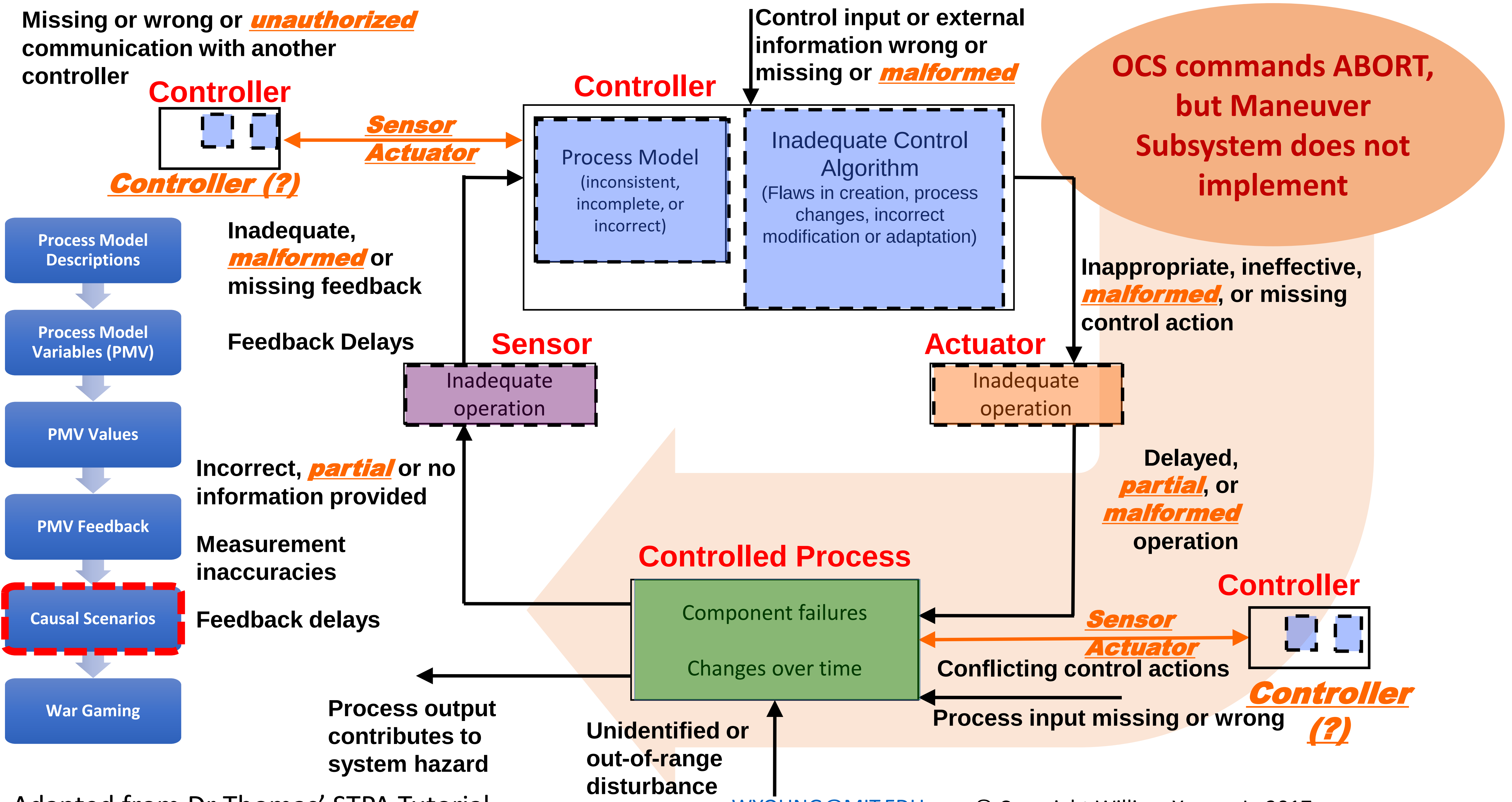
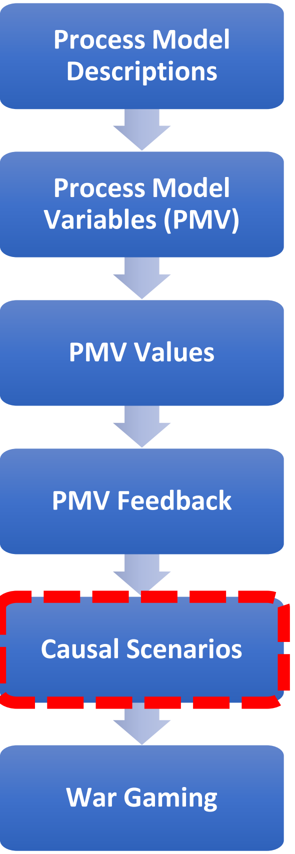
# Potential control actions not followed



# Scenario Discussion




| HCA: Onboard Control System provides ABORT command in close proximity to ISS after receiving ABORT signal from ISS & GSS and close proximity but Maneuver Subsystem does not execute ABORT functionality BECAUSE ___ Scenario___ | | |
|---|---|---|
| **Scenario** | Associated Causal Factors | Rationale/Notes |
| **Maneuver subsystem prioritizes inputs from its internal measurements on whether or not vehicle has exceeded safe docking parameters. Does not adequately handle a case where local sensor data is incorrect AND there are still good comms with ISS / GSS** | | |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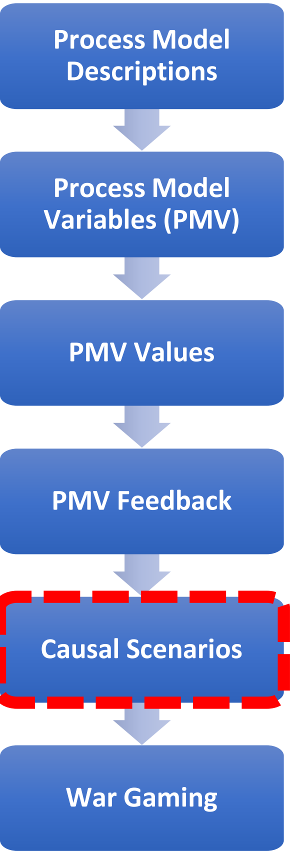
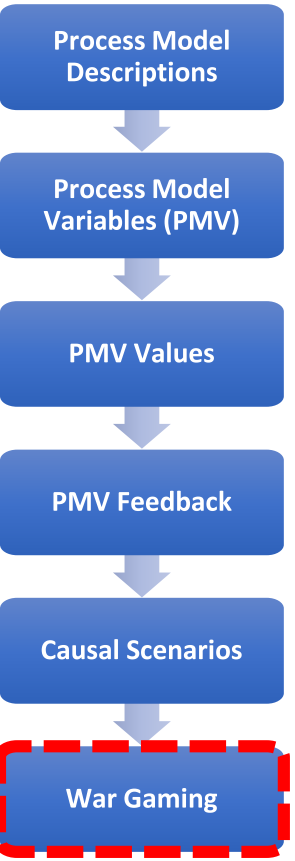
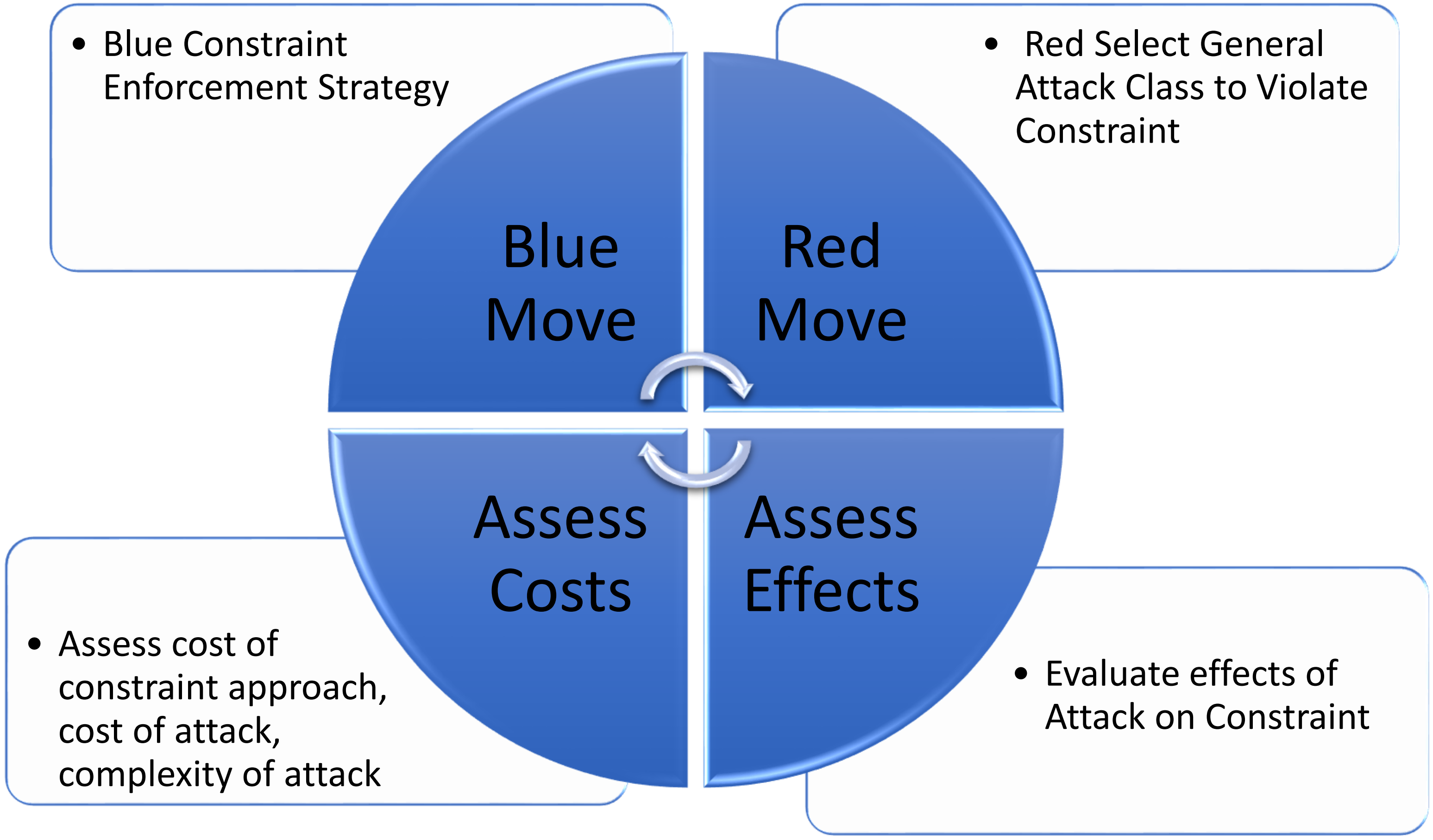
# Scenario Discussion




| HCA: Onboard Control System provides ABORT command in close proximity to ISS after receiving ABORT signal from ISS & GSS and close proximity but Maneuver Subsystem does not execute ABORT functionality BECAUSE ___ Scenario___ | | |
|---|---|---|
| **Scenario** | Associated Causal Factors | Rationale/Notes |
| **Maneuver subsystem prioritizes inputs from its internal measurements on whether or not vehicle has exceeded safe docking parameters. Does not adequately handle a case where local sensor data is incorrect AND there are still good comms with ISS / GSS** | • Inadequate control algorithm<br>• Potential conflicting control between Maneuver subsystem and Onboard control system | Attacking sensor inside Maneuver Subsystem creates the potential to block GSS/ISS if the ABORT logic requires onboard confirmation that the vehicle is in close proximity or outside parameters. |

# Wargaming




**Blue focus on Enforcing Constraint, Red focus on violating constraint…**
**Goal is to “Fix” Problem Through Elimination or Mitigation Above Component Level**



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# User Questions and Answers



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# Summary and Conclusions



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# Lessons Learned Applying STPA-Sec

- Often heard comments:
  - "You're starting at a much higher level of abstraction…"
  - "We try to do something like that, but STPA-Sec is much more rigorous…"
  - "This requires a great deal of thought…from more than just security experts"
- Difficult or impossible to implement if system owner is unable cannot specify what system is supposed to do
- Initial expert guess on what is most important to assure tends to be too broad to be actionable
  - E.g. "Power grid"

**STPA-Sec is NOT a silver bullet, but appears to enable increased rigor "Left of Design"**

# Safety and Security

- **Goal is loss prevention and risk management**
- **Source is probably irrelevant and may be unknowable**
- **Method is the development and engineering of controls**
- **Focus on what we have the ability to address, not the environment**
- **STPA/STPA-Sec provide opportunity for a unified and integrated effort through shared control structure!**

# Conclusion

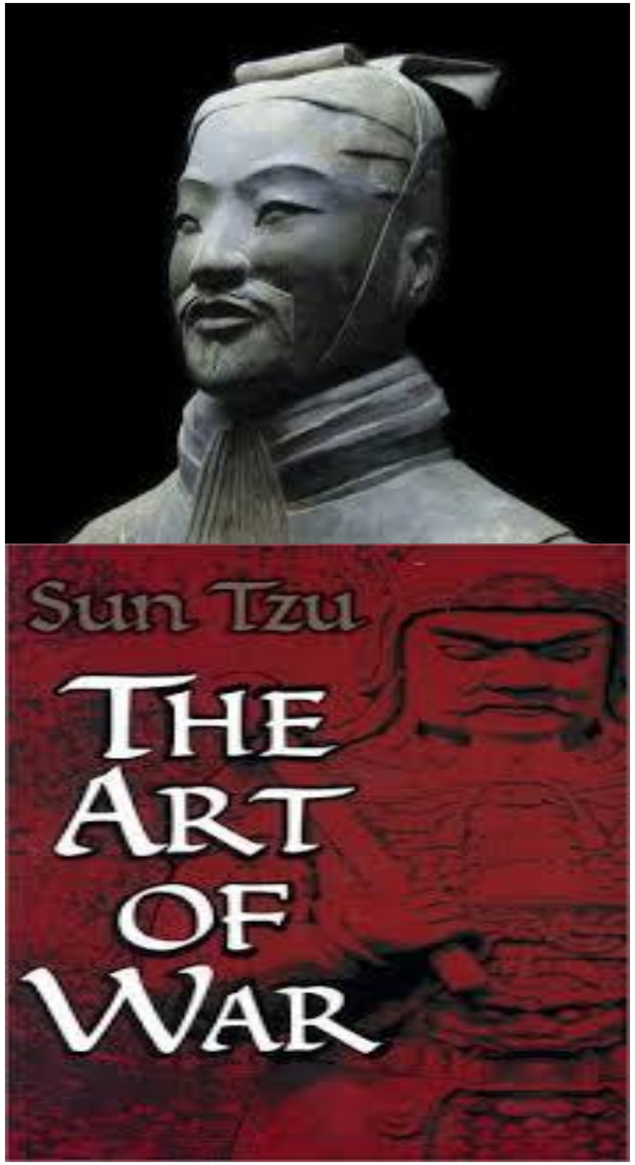
- **Must think carefully about defining the security problem**
- **Perfectly solving the wrong security problem doesn't really help**
- **STPA-Sec provides a means to clearly link security to the broader mission or business objectives**
- **STPA-Sec does not replace existing security engineering methods, but enhances their effectiveness**

# Concluding Thoughts from Sun Tzu

*The opportunity to secure ourselves against defeat lies in our own hands.*

*The supreme art of war is to subdue the enemy without fighting.*

*Strategy without tactics is the slowest route to victory.*
*Tactics without strategy is the noise before defeat.*



QUESTIONS ??