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# Using STPA in the Evaluation of Fighter Pilots Training Programs

## 3rd European STAMP Workshop, STAMP EU 2015



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# Overview



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- **Introduction**
  - **Methodology and Assumptions**
  - **Application of the STPA - Results**
  - **Conclusions**
  - **Recommendations**



# Introduction

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- **Fighter Aircraft Pilots training:**
  - **Currently based on cause-and-effect hazard analysis**
  - **Not embracing systems thinking**
- **Research question: Could an analysis based on the STPA method reveal deficiencies in current fighter pilot training programs?**



# Methodology

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- **Two F-16 A/C, standard A/A configuration.**
- **Air Combat Maneuvers (ACM) in a training area.**
- **Hazards as stated in manuals and SOPs.**
- **Application of the STPA method.**
- **Comparison of results with current training program.**



## Assumptions.

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- **Pilots fit to fly and trained.**
- **Organizational factors not considered.**
- **Airworthy A/C.**



# Application of the STPA



## – Safety Constraints with Control Actions and Feedback Mechanisms.

[In total 9 safety constraints (SCs)]

No	Safety constraints	Control actions	Feedback mechanism
1	Do not violate minimum distance separation 1000ft.	At 9000ft put the head on aircraft 20 degrees off boresight. At 6000ft both aircraft turn towards clear flight path.	<ol style="list-style-type: none"><li>1. Aircraft radar.</li><li>2. HUD track target indicators.</li><li>3. “Brake X” warning message on HUD</li><li>4. “Brake X” warning message on Main Flight Display (MFD).</li><li>5. Closure rate and distance between aircraft (environmental stimuli).</li><li>6. Verbal alert from the wingman</li></ol>



# Application of the STPA



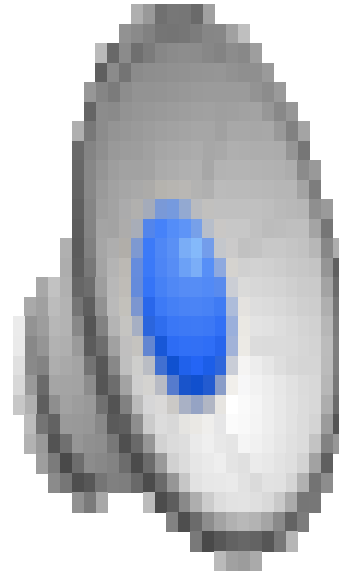
No	Safety constraints	Control actions	Feedback mechanism
2	Do not violate the minimum altitude	Keep minimum altitude	<ol style="list-style-type: none"><li>1. HUD altitude indications.</li><li>2. Analogical altitude indicator.</li><li>3. Warning messages from radio altimeter.</li><li>4. Verbal warnings from aircrafts anti-collision system.</li><li>5. Verbal alert from the wingman.</li></ol>
3	Do not violate the flight control limits in high-performance maneuvers with low airspeed.	Keep the flight control limits during high-performance maneuvers.	<ol style="list-style-type: none"><li>1. HUD airspeed indication.</li><li>2. Analogical airspeed indicator.</li><li>3. Angle of attack indexers</li><li>4. Voice warning (horn) for low speed and high nose-up angle.</li><li>5. Aircraft response to pilots' action.</li></ol>





# Violated Safety Constraint.

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# Combined SCs in ACM mission



SC	1	2	3	4	5	6	7	8	9
1		S	S	S	S	S	S		S
2	S		S	S	S	S	S		S
3				S			S		S
4	S	S	S		S	S	S		S
5		S	M	S		S	S		S
6	S	S	S	S	S				S
7				S					S
8	S	S	S	S	S	S	S		S
9	S	S	S	S	S	S	S		

S: Simultaneous, M: Masked



# Observations from the first steps of the STPA

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- a. **The Head-Up Display (HUD): basic feedback mechanism for 6 out of the 9 constraints.**
- b. **Vision, audition and vestibular senses required in various SC combinations.**



# Observations from the first steps of the STPA



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SC:	1	2	3	4	5	6	7	8	9
Sight	1/5	1/3	0/3	1/2	0/3	0/2	0/2	0/1	
Hearing	1/1	2/2	1/1				1/1	1/1	1/1
Vestibular			0/1		0/1				

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Senses Used to Receive Information from Feedback  
Mechanisms



# Observations from the first steps of the STPA



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SCs violated:	1+2	1+2+3	1+2+3+4	1+2+3+4+5	1+2+3+4+ 5+6	1+2+3+4+ 5+6+7	1+2+3+4+5+6 +7+9
Number of visual alerts (on HUD / on other displays or instruments)*	1/2	1/2	2/2	2/2	2/2	2/2	2/2
Number of audio alerts*	2	3	3	3	3	3	4
Requirements to consult other indications (on the HUD / on other displays, instruments / physical environment)*	2/2/1	3/4/1	3/5/1	4/6/1	4/6/1	4/6/1	4/6/1

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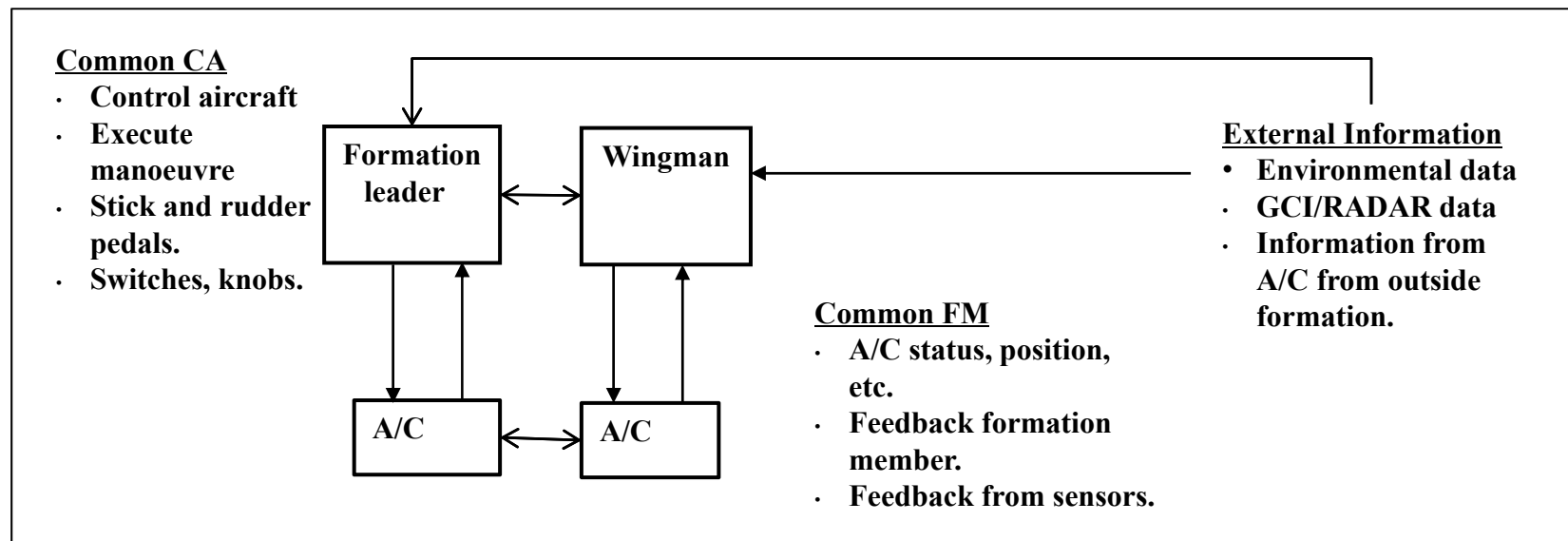
\* Feedback mechanisms related to multiple SCs were considered once.

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## Feedback Mechanisms in Multiple SC Violations



# Basic Control Loop.



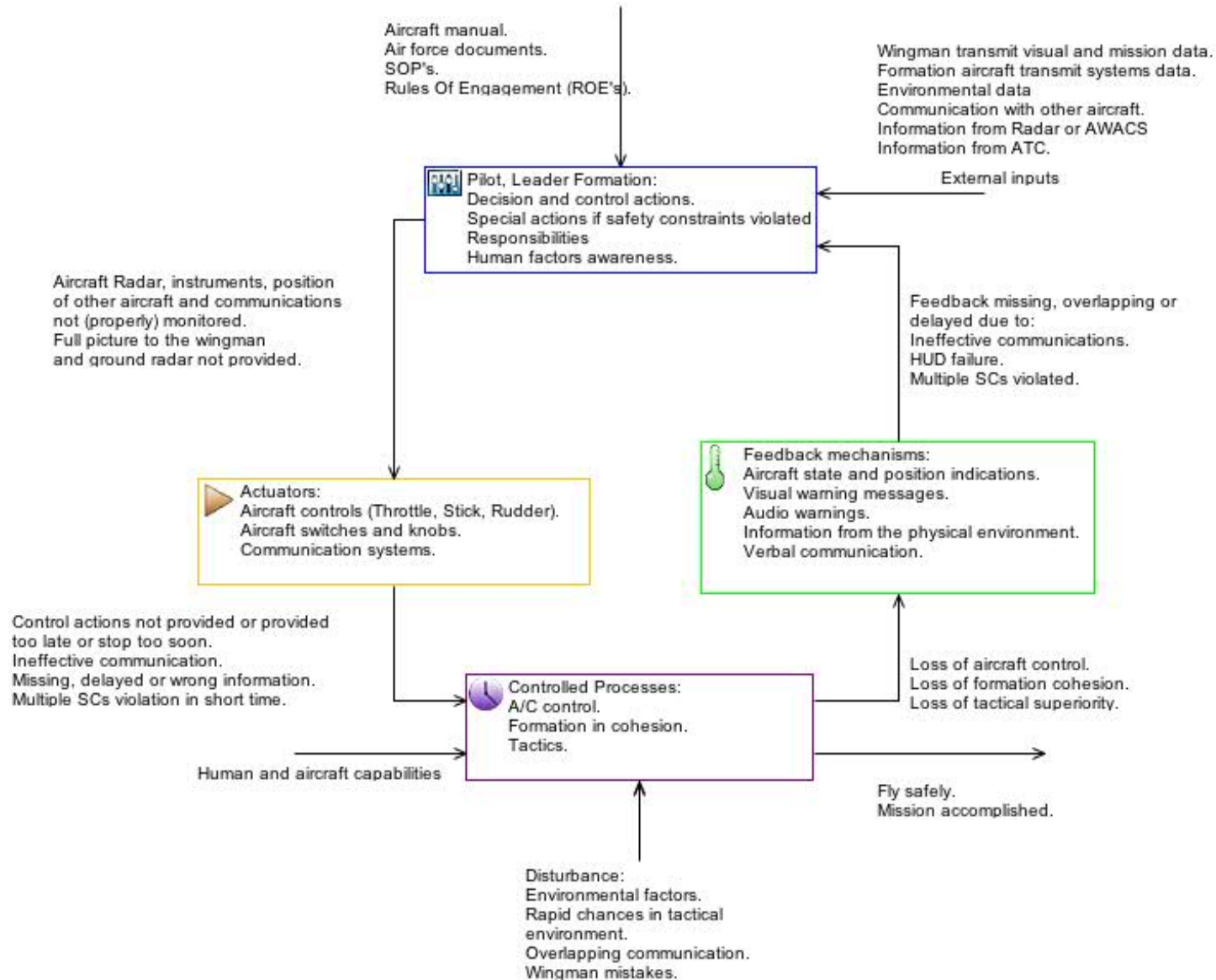


# Hazardous States

No	Control Action	Hazardous States			
		Not provided	Provided (incorrectly)	Applied too late	Stopped too soon
1	<p>Keep 1000ft minimum distance separation between aircraft, by applying the follow rules:</p> <p>At 9000ft put the head on aircraft 20 degrees off boresight.</p> <p>At 6000ft both aircraft turn towards clear flight path.</p>		<ol style="list-style-type: none"><li>1. Unsafe separation between aircraft.</li><li>2. Loss of aircraft control due to exposure to exhaust gasses of formation aircraft.</li></ol>		
2	Keep minimum altitude		Flying too close to the terrain.		
3	Keep the flight control limits during high-performance maneuvers.		<ol style="list-style-type: none"><li>1. Loss of aircraft control due to disturbance of aerodynamic capabilities.</li><li>2. Unsafe separation between aircraft.</li></ol>		



# Control Flow for the Formation Leader







# Conclusions

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- **Flight Training is currently based on independent SCs.**
- **The application of STPA revealed potential flaws even from the first steps.**
- **Maintenance of some SCs rely on one sense only.**



# Conclusions

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- **When multiple SCs infringed:**
  - **If HUD fails pilot's workload increases considerably.**
  - **Prioritization of actions not supported by procedures and/or technology.**
  - **Alerts and warnings from feedback mechanisms might overlap and impede human performance.**



# Recommendations



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- a. A systemic approach is expected to benefit flight training.**
  - b. Scenarios with multiple violations of SCs must be included in flight training.**
  - c. Maintenance of all SCs must be supported by alerts and not relied on one sense.**
  - d. Technology and procedures need to facilitate the prioritization of actions under infringement of multiple SCs.**



## Recommendations



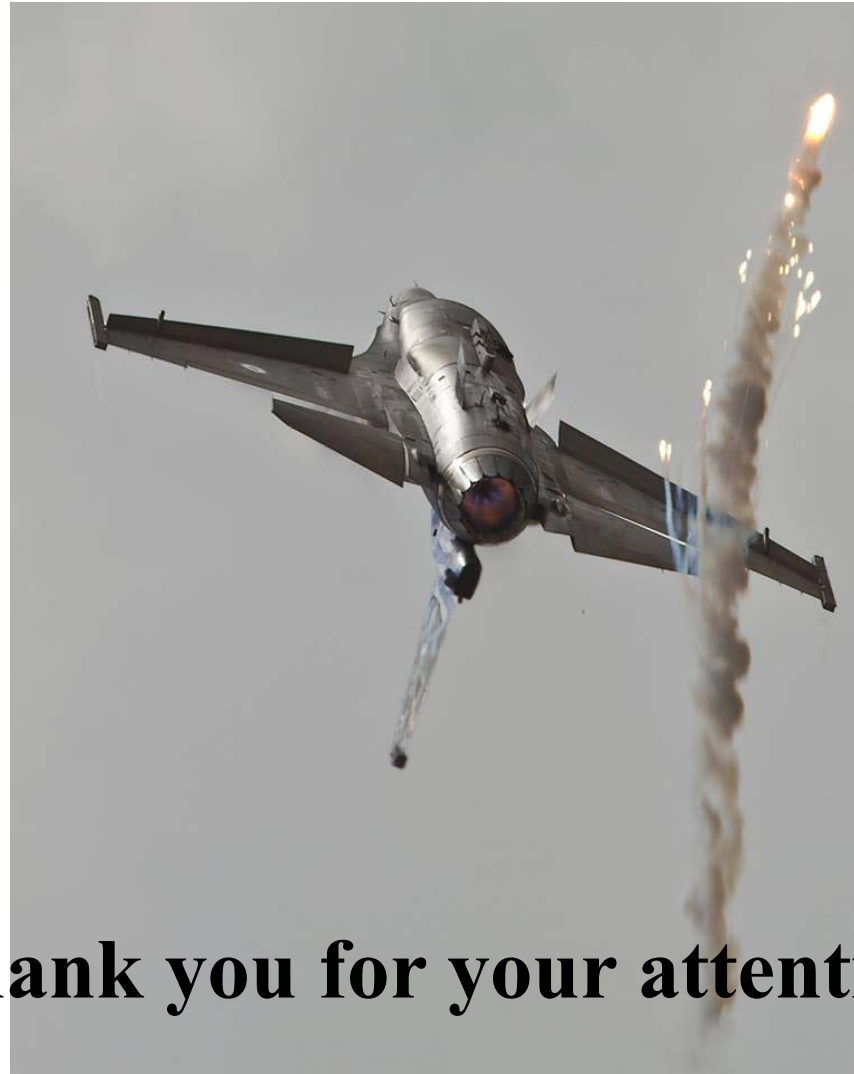
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**e. Application of STPA methodology needs to consider:**

- Multiple SCs violations as causal factors.**
- Potential implications on human performance when alerts from multiple feedback mechanisms might overlap.**



# Questions?



**Thank you for your attention!**

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