INCOSE Symposium 2010

RELAAy

A Tool to Guide HSI Requirements

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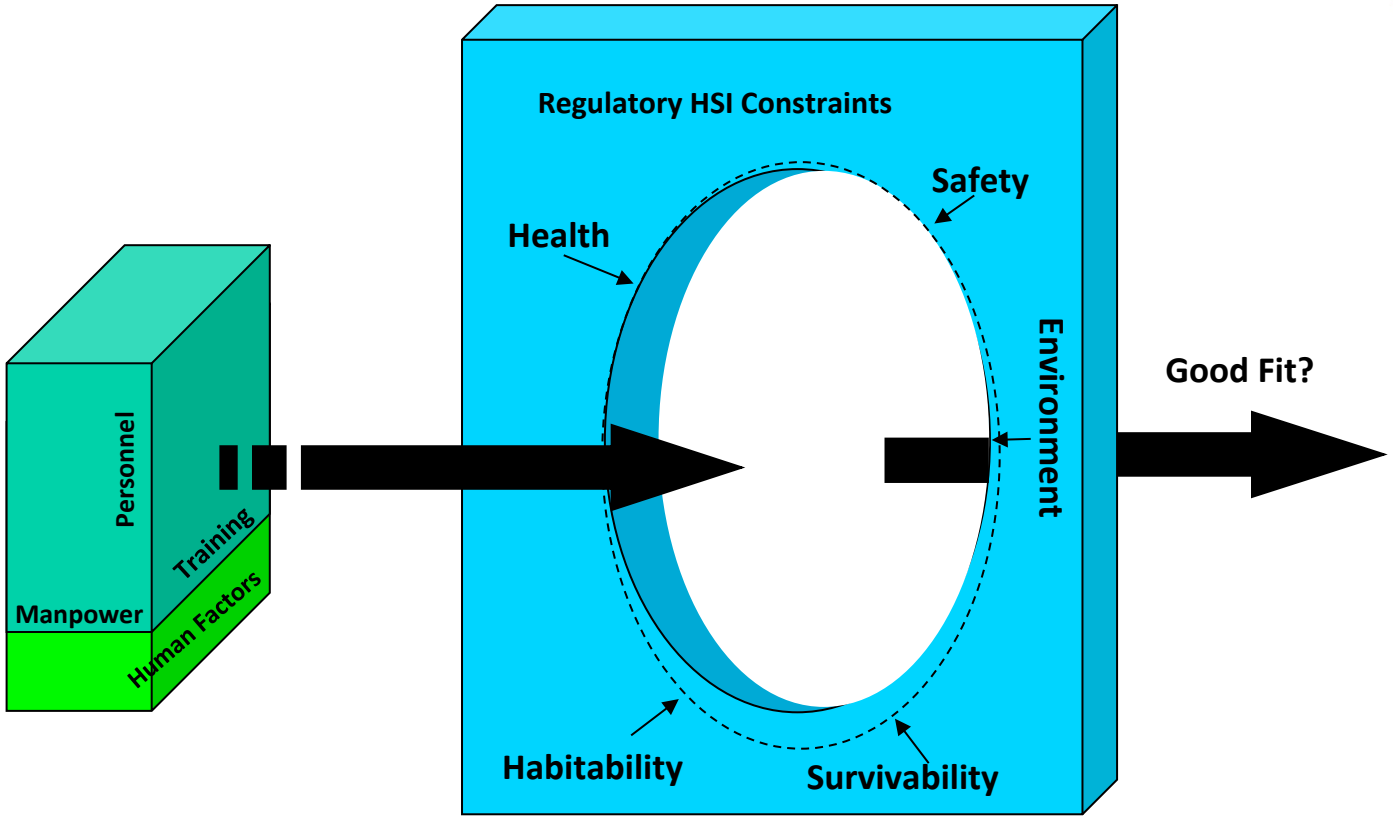
- *The views expressed in this presentation are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States Government.*

Human Systems Integration

-- Interdisciplinary technical and management processes for integrating human considerations within and across all system elements;

…an essential enabler to systems engineering practice.

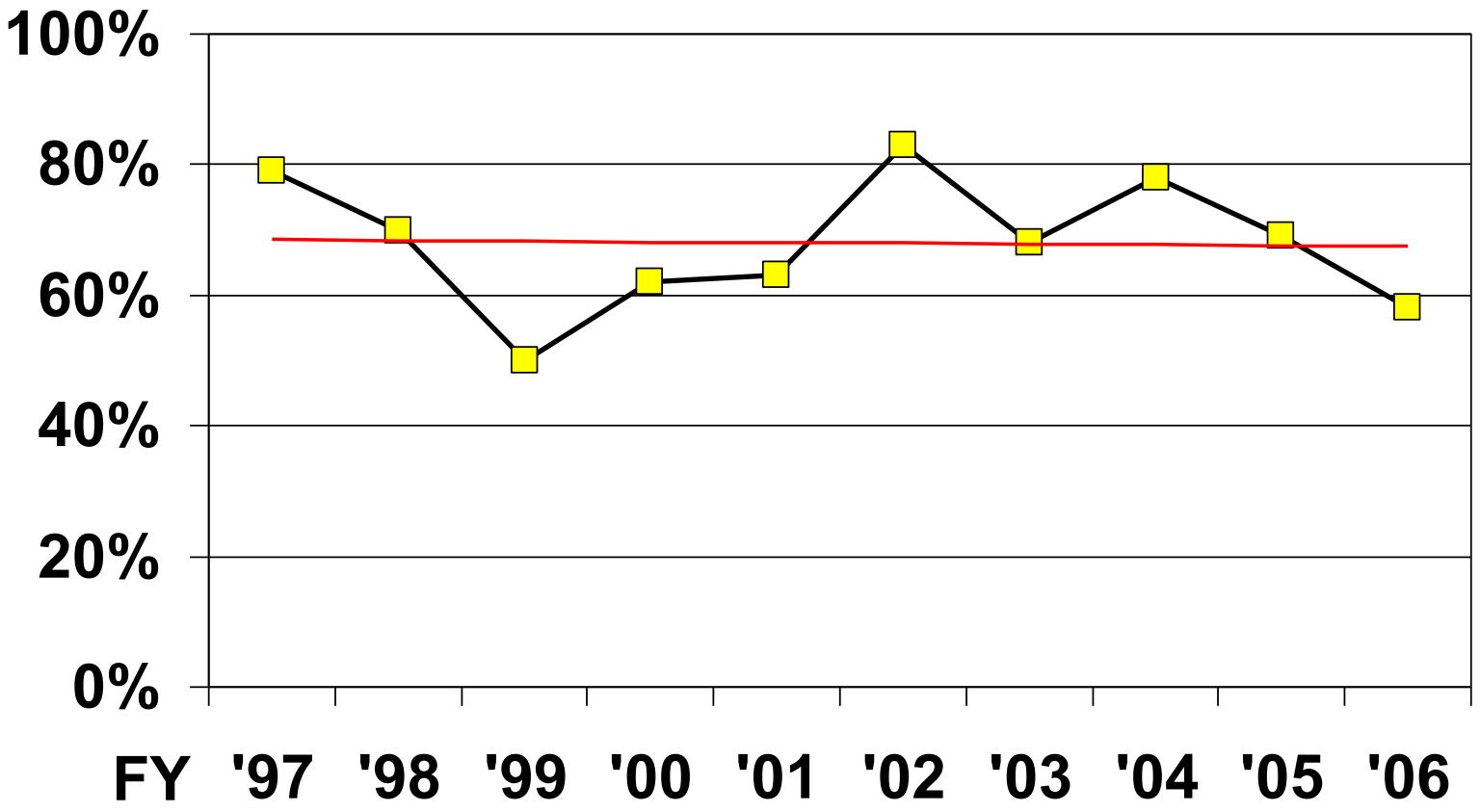
Systems Engineering and HSI



HSI – An interdisciplinary technical and management processes for integrating human considerations within and across all system elements; an essential enabler to systems engineering practice.

Motivation: Aviation Mishaps

Annual Percentage of Mishaps Attributed to Human-related Factors



Source: AFSC

The (Missing) SE Feedback

Systems Analysis
- Platform-specific
- System modifications

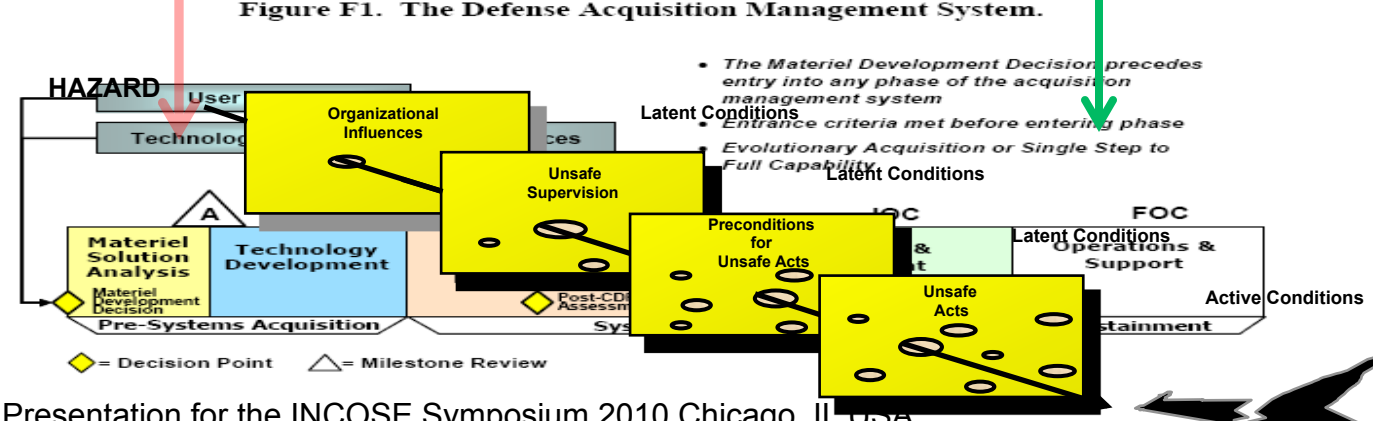
Operational Analysis
- Organization-specific
- Tactics and procedures
- Training, Workarounds

Prevention
- Feedback HSI requirements to new systems
- Balance requirements
- Cross-platform

Mitigation
- Mishap Review Panels
- Safety Analysis Reports

Investigation
- "What" happened
- Recommendations

Classification
- Group and sort
- HFACS (for human issues)



Requirements Elicitation through Legacy Accident Analysis (RELAAy)

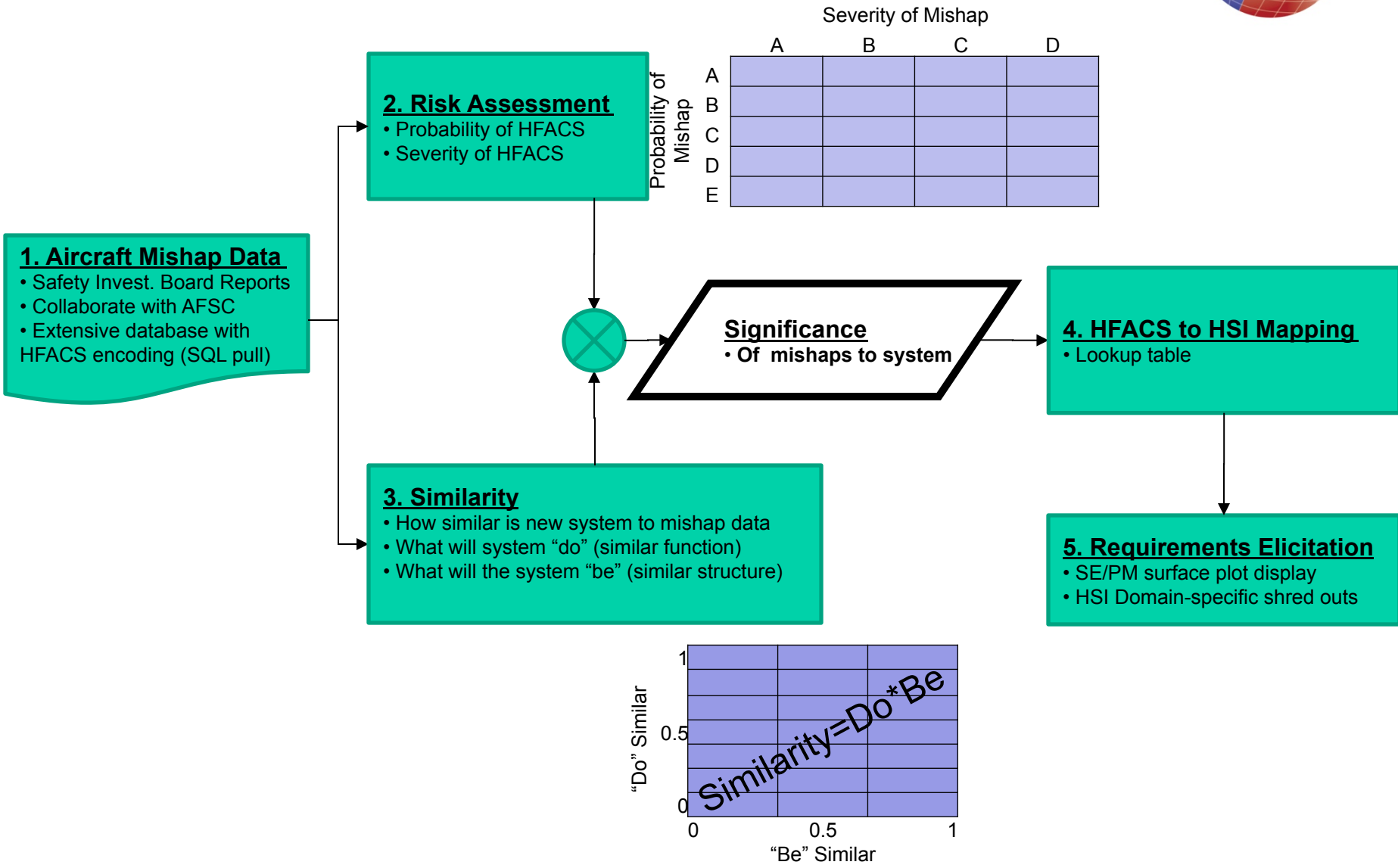
Proposed Method Summary

- Study mishaps in legacy systems where human error was identified as a causal factor
- Quantify the effect of human-machine interaction breakdowns in new systems
- Use that empirical data to predict, and justify, requirements for new system design

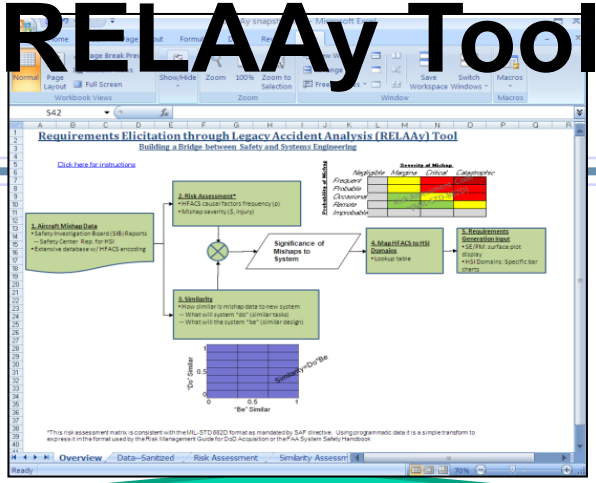
Data Sources

- DoD and USAF Instructions on mishap investigations
- USAF Safety Investigation Board (SIB) reports
- USAF/DoD Instructions on Safety Risk Analysis

The Process


Severity of Mishap
A
B
C
D
Probability of Mishap
A
B
C
D
E
2. Risk Assessment
• Probability of HFACS
• Severity of HFACS
1. Aircraft Mishap Data
• Safety Invest. Board Reports
• Collaborate with AFSC
• Extensive database with HFACS encoding (SQL pull)
Significance
• Of mishaps to system
4. HFACS to HSI Mapping
• Lookup table
3. Similarity
• How similar is new system to mishap data
• What will system "do" (similar function)
• What will the system "be" (similar structure)
5. Requirements Elicitation
• SE/PM surface plot display
• HSI Domain-specific shred outs
"Do" Similar
1
0.5
0
Similarity=Do*Be
0
0.5
1
"Be" Similar

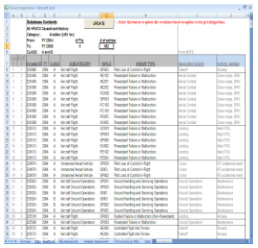
RELAAy Tool



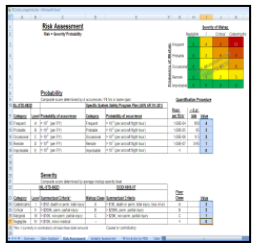
- Excel-based tool
- Receives SQL data pull
- VBA® coded
- Pivot table presentation

Privileged Mishap Data
(External File)

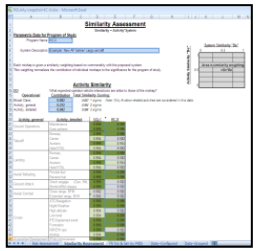
Sanitized Data
(2nd worksheet)



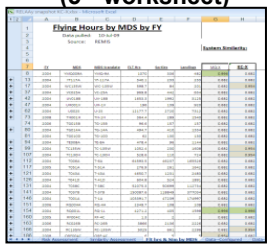
Risk Assessment
(3rd worksheet)



Similarity
(4th worksheet)



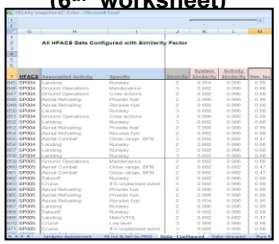
Scale Flight Hrs Apply Similarity
(5th worksheet)



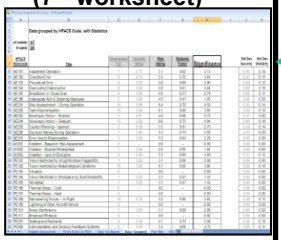
HFACS Data Analysis

HSI Domains Analysis

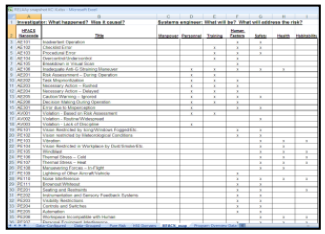
HFACS events w/ Similarity
(6th worksheet)



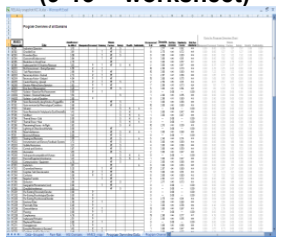
Grouped/ Sorted HFACS Codes
(7th worksheet)



HFACS to HSI Map
(8th worksheet)



Program/System Data Analysis
(9-13th worksheet)



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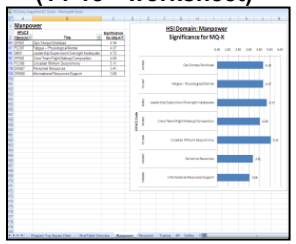
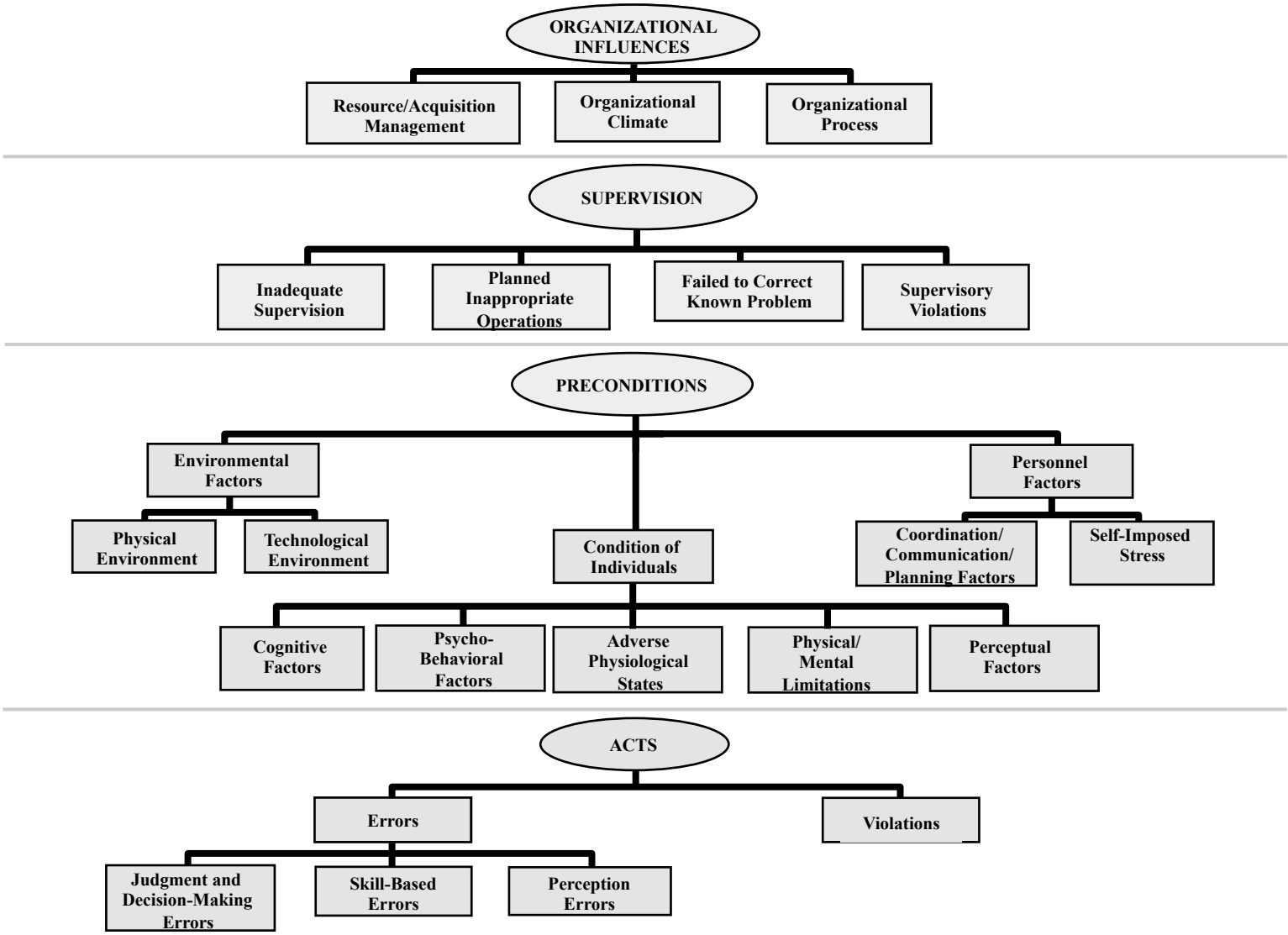
HSI Domain Statistics
(14-18th worksheet)



DoD Human Error Taxonomy (formerly DoD-HFACS)



1. Mishap Data

HFACS Nanocode	Title	Occurences/ 5 yr	Severity rating	Risk Rating	Similarity Factor
AE101	Inadvertent Operation	7	2.71	5.1	0.62
AE102	Checklist Error	8	2.75	5.3	0.65
AE103	Procedural Error	8	3.00	5.8	0.65
AE104	Overcontrol/Undercontrol	9	3.00	5.9	0.60
AE105	Breakdown in Visual Scan	4	3.00	4.9	0.57
AE106	Inadequate Anti-G Straining Maneuver	2	3.00	4.0	0.47
AE201	Risk Assessmnent – During Operation	16	2.88	6.4	0.66
AE202	Task Misprioritization	10	3.00	6.1	0.57
AE203	Necessary Action – Rushed	3	2.67	4.0	0.68
AE204	Necessary Action – Delayed	15	3.00	6.6	0.65
AE205	Caution/Warning – Ignored	2	2.50	3.3	0.68
AE206	Decision Making During Operation	7	2.86	5.3	0.62
AE301	Error due to Misperc				
AV001	Violation - Based on				
AV002	Violation - Routine/V				
AV003	Violation - Lack of D				
PE101	Vision Restricted by				
PE102	Vision restricted by I				
PE103	Vibration				
PE104	Vision Restricted in				
PE105	Windblast				

FY	CLASS	SUBCATEGORY	HFACS	MISHAP TYPE
2004	A	Aircraft Flight	AE204	Controlled Flight Into Terrain
2004	A	Aircraft Flight	PC307	Controlled Flight Into Terrain
2004	A	Aircraft Flight	PC508	Controlled Flight Into Terrain
2004	A	Aircraft Flight	PC509	Controlled Flight Into Terrain

2. Risk Rating

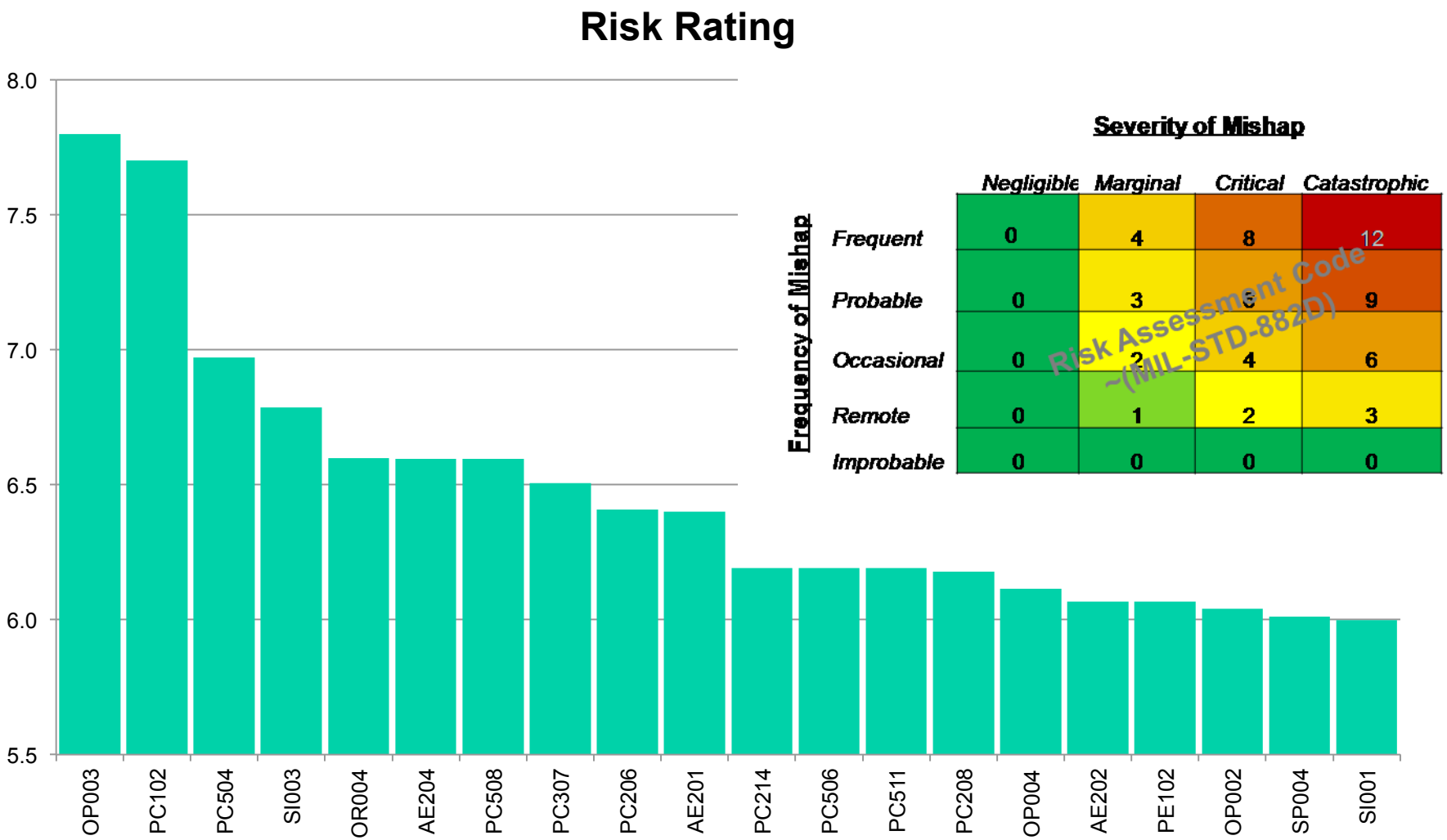
Severity

MIL-STD-882D			DODI 6055.07		Quantified	
Category	Level	Summarized Criteria*	Mishap Class	Summarized Criteria	Class	Value
Catastrophic	I	> $1M, death or perm. total injury	A	> $1M, death or perm. total injury, loss of a/c	A	**3**
Critical	II	> $200K, perm. partial injury	B	> $200K, perm. partial injury	B	**2**
Marginal	III	> $10K, non-perm. partial injury	C	> $20K, non-perm. partial injury	C	**1**
Negligible	IV	< $10K, minor medical	--		<	**0**

Frequency (Probability of Mishap)

MIL-STD-882D			Specific System Safety Program Plan (IAW AFI 91-301)		Quantified		
Category	Level	Probability of occurrence	Category	Probability of occurrence	Floor per flt hr	~5 yr rate	Value
Frequent	A	> 10^{-1} (per FY)	Frequent	> 10^{-4} (per flt hr)	10^{-4}	950	4
Probable	B	> 10^{-2} (per FY)	Probable	> 10^{-5} (per flt hr)	10^{-5}	95	3
Occasional	C	> 10^{-3} (per FY)	Occasional	> 10^{-6} (per flt hr)	10^{-6}	9.5	2
Remote	D	> 10^{-6} (per FY)	Remote	> 10^{-7} (per flt hr)	10^{-7}	0.95	1
Improbable	E	< 10^{-6} (per FY)	Improbable	< 10^{-7} (per flt hr)	<		0

2. Risk Rating



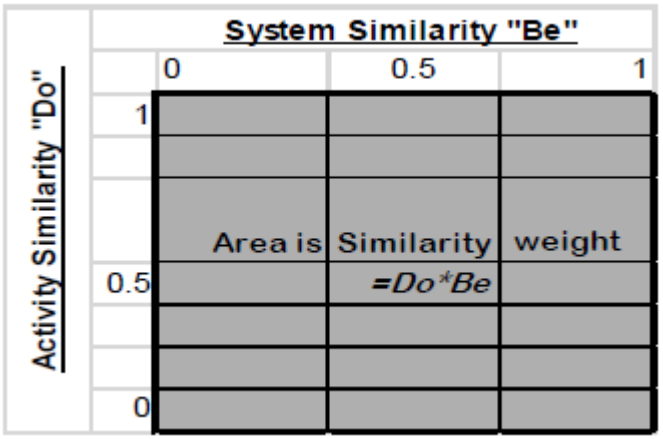
3. Similarity Weighting

- **Each mishap is given a similarity weighting based on commonality with the proposed system**

- **This weighting normalizes the contribution of individual mishaps to the significance for the program of study.**

Physical	**Contribution**	**Total Similarity Scoring:**	
Vehicle Class (FAA)*	**0.682**	*0.682*	*1 sigma*
MDS Class	**0.272**	*0.954*	*2 sigma*
Same weapons system*	**0.042**	*0.996*	*3 sigma*

Operational	**Contribution**	**Total Similarity Scoring:**	
Broad Class	**0.682**	*0.682*	*1 sigma*
Activity, general	**0.272**	*0.954*	*2 sigma*
Activity, detailed	**0.042**	*0.996*	*3 sigma*



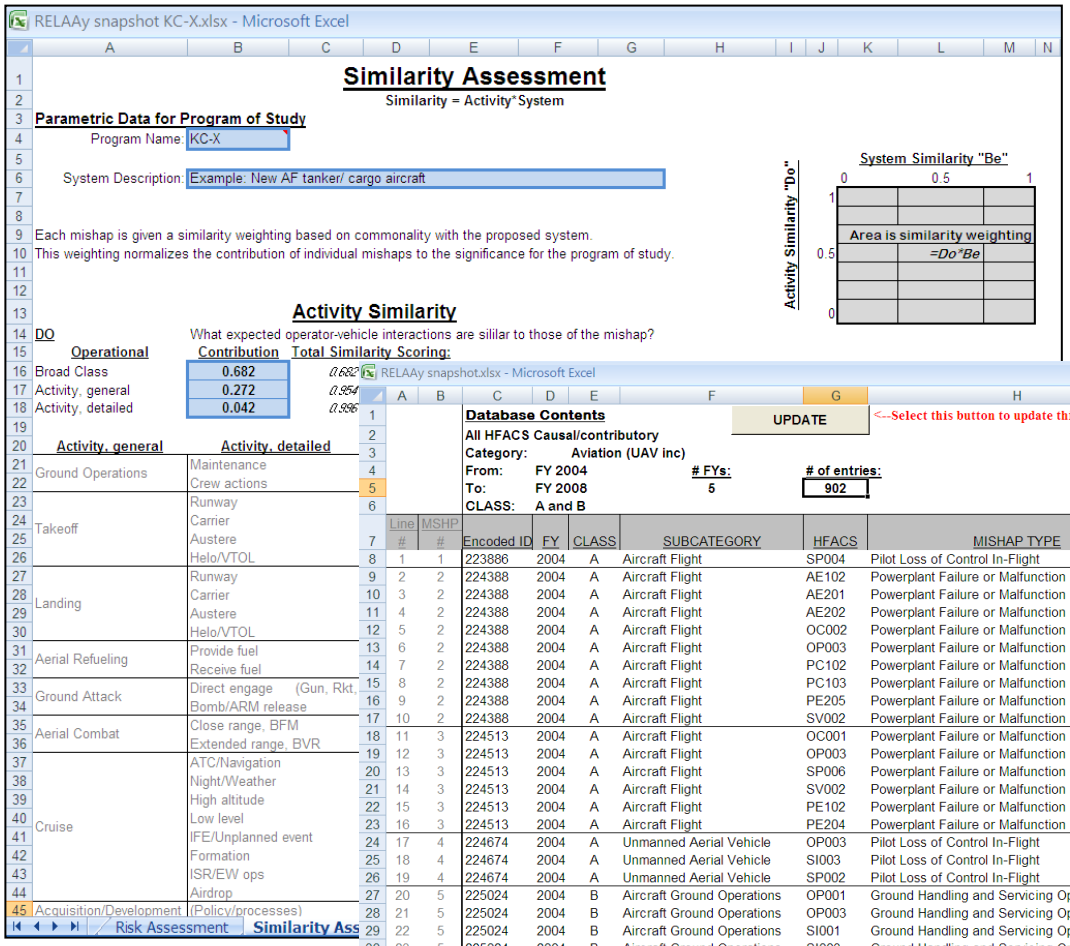
3. Similarity Weighting

- **Chosen application: MQ-X (next Predator-class of vehicles)**

- **Planned Capabilities:**
  - **Transit commercial airspace**
  - **Aerial refueling (send/receive)**
  - **Surveillance / Reconnaissance**
  - **Close air support**
  - **Strategic strike**

Artist's rendition (LM Skunk Works)

3. Similarity Weighting



RELAAy snapshot KC-X.xlsx - Microsoft Excel

Similarity Assessment

Similarity = Activity*System

Parametric Data for Program of Study

Program Name: KC-X

System Description: Example: New AF tanker/ cargo aircraft

Each mishap is given a similarity weighting based on commonality with the proposed system.
This weighting normalizes the contribution of individual mishaps to the significance for the program of study.

System Similarity "Be"

Activity Similarity "Do"

Area is similarity weighting =Do*Be

Activity Similarity

DO — What expected operator-vehicle interactions are sililar to those of the mishap?

Operational	Contribution	Total Similarity Scoring:
Broad Class	0.682	0.682
Activity, general	0.272	0.954
Activity, detailed	0.042	0.996

Activity, general	Activity, detailed
Ground Operations	Maintenance
	Crew actions
Takeoff	Runway
	Carrier
	Austere
	Helo/VTOL
Landing	Runway
	Carrier
	Austere
	Helo/VTOL
Aerial Refueling	Provide fuel
	Receive fuel
Ground Attack	Direct engage (Gun, Rkt,
	Bomb/ARM release
Aerial Combat	Close range, BFM
	Extended range, BVR
Cruise	ATC/Navigation
	Night/Weather
	High altitude
	Low level
	IFE/Unplanned event
	Formation
	ISR/EW ops
	Airdrop
Acquisition/Development	(Policy/processes)

Risk Assessment | Similarity Ass

RELAAy snapshot.xlsx - Microsoft Excel

Database Contents

UPDATE <--Select this button to update this worksheet based on updates to the priviledged data.

All HFACS Causal/contributory
Category: Aviation (UAV inc)
From: FY 2004
To: FY 2008
CLASS: A and B

FYs: 5

of entries: 902

Line #	MSHP #	Encoded ID	FY	CLASS	SUBCATEGORY	HFACS	MISHAP TYPE	From MOFE: Associated Activity	Activity, detailed
1	1	223886	2004	A	Aircraft Flight	SP004	Pilot Loss of Control In-Flight	Takeoff	Runway
2	2	224388	2004	A	Aircraft Flight	AE102	Powerplant Failure or Malfunction	Aerial Combat	Close range, BFM
3	2	224388	2004	A	Aircraft Flight	AE201	Powerplant Failure or Malfunction	Aerial Combat	Close range, BFM
4	2	224388	2004	A	Aircraft Flight	AE202	Powerplant Failure or Malfunction	Aerial Combat	Close range, BFM
5	2	224388	2004	A	Aircraft Flight	OC002	Powerplant Failure or Malfunction	Aerial Combat	Close range, BFM
6	2	224388	2004	A	Aircraft Flight	OP003	Powerplant Failure or Malfunction	Aerial Combat	Close range, BFM
7	2	224388	2004	A	Aircraft Flight	PC102	Powerplant Failure or Malfunction	Aerial Combat	Close range, BFM
8	2	224388	2004	A	Aircraft Flight	PC103	Powerplant Failure or Malfunction	Aerial Combat	Close range, BFM
9	2	224388	2004	A	Aircraft Flight	PE205	Powerplant Failure or Malfunction	Aerial Combat	Close range, BFM
10	2	224388	2004	A	Aircraft Flight	SV002	Powerplant Failure or Malfunction	Aerial Combat	Close range, BFM
11	3	224513	2004	A	Aircraft Flight	OC001	Powerplant Failure or Malfunction	Landing	Helo/VTOL
12	3	224513	2004	A	Aircraft Flight	OP003	Powerplant Failure or Malfunction	Landing	Helo/VTOL
13	3	224513	2004	A	Aircraft Flight	SP006	Powerplant Failure or Malfunction	Landing	Helo/VTOL
14	3	224513	2004	A	Aircraft Flight	SV002	Powerplant Failure or Malfunction	Landing	Helo/VTOL
15	3	224513	2004	A	Aircraft Flight	PE102	Powerplant Failure or Malfunction	Landing	Helo/VTOL
16	3	224513	2004	A	Aircraft Flight	PE204	Powerplant Failure or Malfunction	Landing	Helo/VTOL
17	4	224674	2004	A	Unmanned Aerial Vehicle	OP003	Pilot Loss of Control In-Flight	Cruise	IFE/unplanned event
18	4	224674	2004	A	Unmanned Aerial Vehicle	SI003	Pilot Loss of Control In-Flight	Cruise	IFE/unplanned event
19	4	224674	2004	A	Unmanned Aerial Vehicle	SP002	Pilot Loss of Control In-Flight	Cruise	IFE/unplanned event
20	5	225024	2004	B	Aircraft Ground Operations	OP001	Ground Handling and Servicing Operations	Ground Operations	Maintenance
21	5	225024	2004	B	Aircraft Ground Operations	OP003	Ground Handling and Servicing Operations	Ground Operations	Maintenance
22	5	225024	2004	B	Aircraft Ground Operations	SI001	Ground Handling and Servicing Operations	Ground Operations	Maintenance
23	5	225024	2004	B	Aircraft Ground Operations	SI003	Ground Handling and Servicing Operations	Ground Operations	Maintenance
24	5	225024	2004	B	Aircraft Ground Operations	SP002	Ground Handling and Servicing Operations	Ground Operations	Maintenance
25	5	225024	2004	B	Aircraft Ground Operations	SP005	Ground Handling and Servicing Operations	Ground Operations	Maintenance
26	6	225316	2004	A	Aircraft Flight	OP003	System Failure or Malfunction (Non-Powerplant)	Landing	Runway
27	7	225588	2004	B	Aircraft Ground Operations	OP003	Powerplant Failure or Malfunction	Ground Operations	Maintenance
28	8	225573	2004	A	Aircraft Flight	AE202	Controlled Flight Into Terrain	Takeoff	Runway
29	8	225573	2004	A	Aircraft Flight	AE204	Controlled Flight Into Terrain	Takeoff	Runway

Overview | Data--Sanitized | Risk Assessment | Similarity Assessment | Flt hrs & Sim by MDS | Data-

Significance

Target system: MQ-X

Nanocode	Title	Occurences/ 5 yr	Severity rating	Risk Rating	Similarity Factor	Significance
PP111	Task/Mission-In-Progress Re-Planning	1	3.00	3.1	0.65	2.00
PP112	Miscommunication	3	2.67	4.0	0.68	2.72
PP201	Physical Fitness	0	--	0.0	--	0.00
PP202	Alcohol	2	3.00	4.0	0.68	2.70
PP203	Drugs/Supplements/Self Medication	0	--	0.0	--	0.00
PP204	Nutrition	1	3.00	3.1	0.47	1.43
PP205	Inadequate Rest	2	3.00	4.0	0.57	2.27
PP206	Unreported Disqualifying Medical Condition	0	--	0.0	--	0.00
SI001	Leadership/Supervision/Oversight Inadequate	30	2.40	6.0	0.69	4.11
SI002	Supervision – Modeling	2	3.00	4.0	0.84	3.32
SI003	Local Training Issues/Programs	44	2.55	6.8	0.73	4.99
SI004	Supervision – Policy	9	2.33	4.6	0.78	3.61
SI005	Supervision – Personality Conflict	1	2.00	2.0	0.68	1.39

Significance

Compare top 10 HFACS

Risk alone	w/ Sim_factor
OP003	OP003
PC102	SI003
PC504	OR004
SI003	PC102
OR004	OP002
AE204	OP001
PC508	SP004
PC307	OP004
PC206	OC001
AE201	PC508

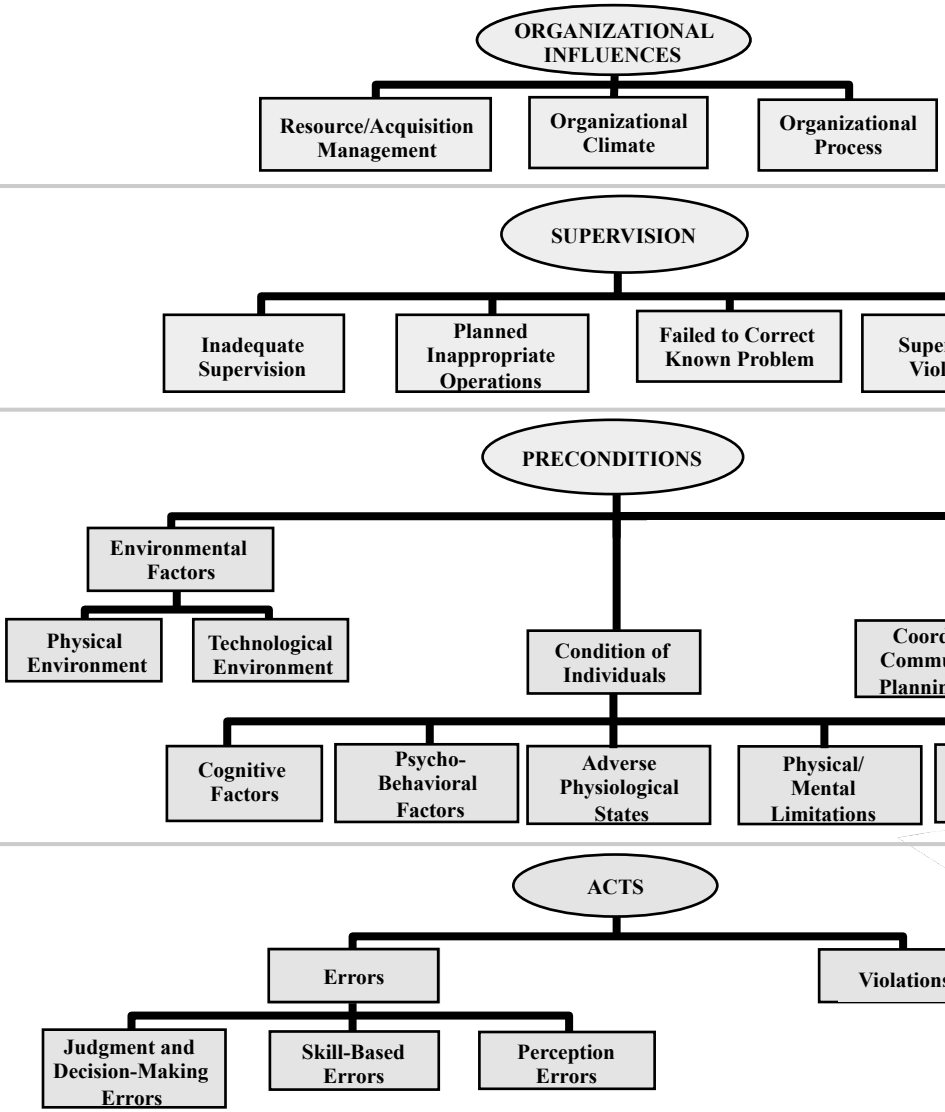
50% common

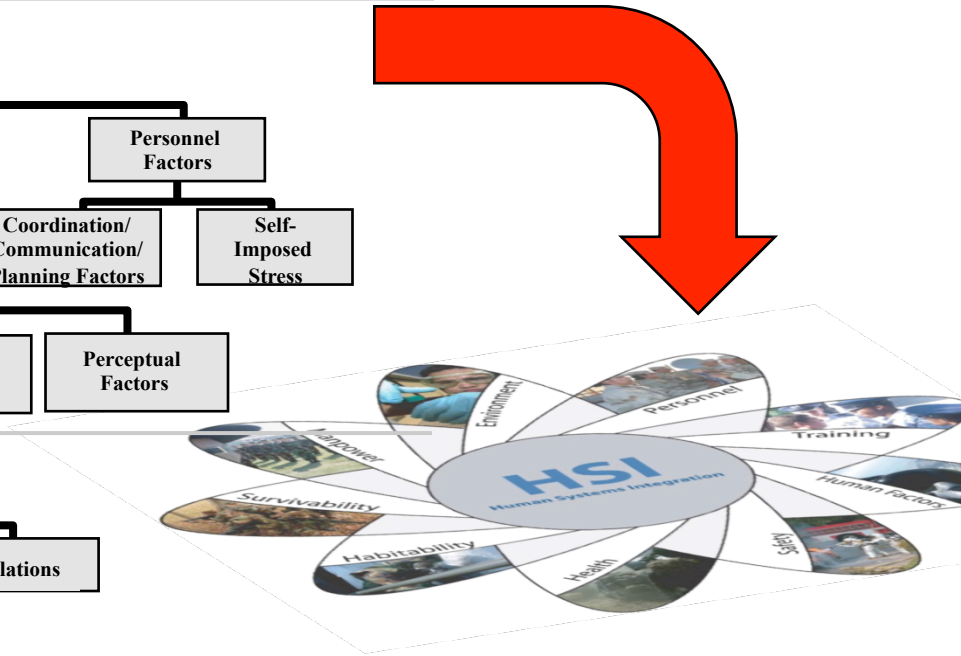
Compare top 20 HFACS

Risk alone	w/ Sim_factor
OP003	OP003
PC102	SI003
PC504	OR004
SI003	PC102
OR004	OP002
AE204	OP001
PC508	SP004
PC307	OP004
PC206	OC001
AE201	PC508
PC214	AE204
PC506	AE201
PC511	SV001
PC208	PC307
OP004	SF002
AE202	PC504
PE102	PC208
OP002	PC511
SP004	SI001
SI001	PC206

80% common

4. HFACS→HSI Domain Mapping



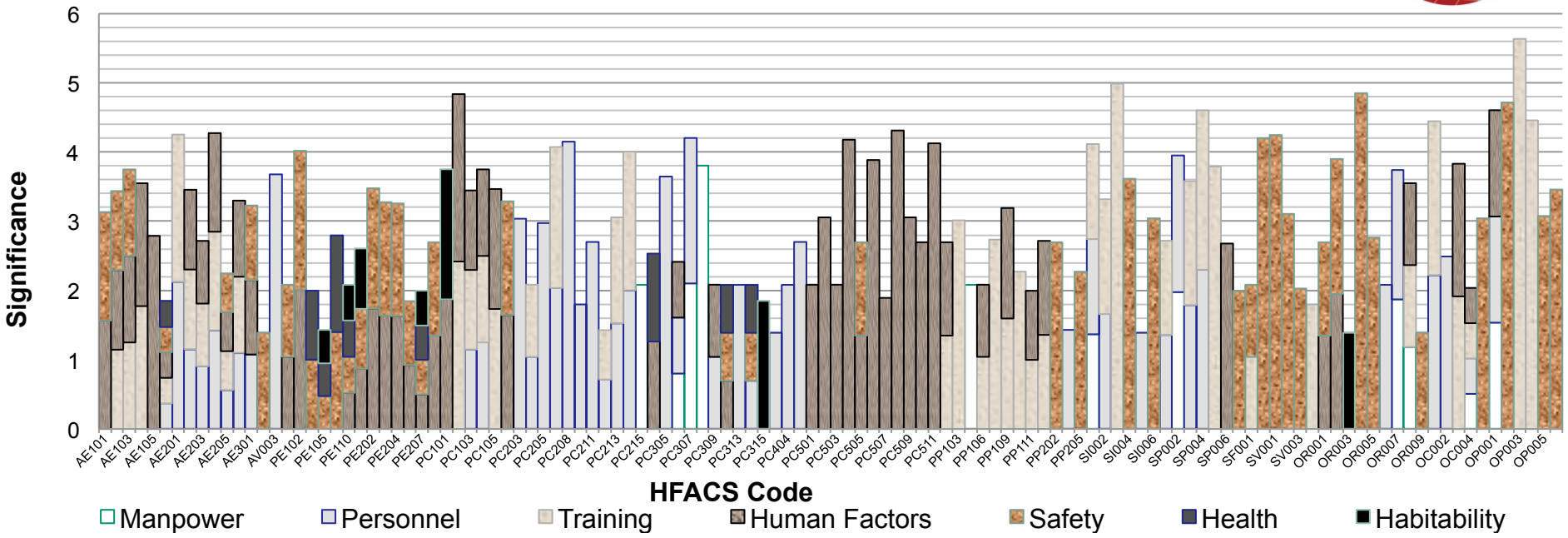


4. HFACS→HSI Domain Mapping

HFACS Nanocode	Title	Manpower	Personnel	Training	Human Factors	Safety	Health	Habitability
AE101	Inadvertent Operation				x	x		
AE102	Checklist Error			x	x	x		
AE103	Procedural Error			x	x	x		
AE104	Overcontrol/Undercontrol			x	x			
AE105	Breakdown in Visual Scan				x			
AE106	Inadequate Anti-G Straining Maneuver		x	x	x	x	x	
AE201	Risk Assessmnent – During Operation		x	x				
AE202	Task Misprioritization		x	x	x			
AE203	Necessary Action – Rushed		x	x	x			
AE204	Necessary Action – Delayed		x	x	x			
AE205	Caution/Warning – Ignored		x	x	x	x		
AE206	Decision Making During Operation		x	x	x			
AE301	Error due to Misperception		x		x	x		
AV001	Violation - Based on Risk Assessment		x	x				
AV002	Violation - Routine/Widespread					x		
AV003	Violation - Lack of Discipline		x					
PE101	Vision Restricted by Icing/Windows Fogged/Etc.				x	x		
PE102	Vision restricted by Meteorological Conditions				x	x		
PE103	Vibration					x	x	x
PE104	Vision Restricted in Workplace by Dust/Smoke/Etc.					x	x	
PE105	Windblast					x	x	x
PE106	Thermal Stress – Cold					x	x	x
PE107	Thermal Stress – Heat					x	x	x
PE108	Manuevering Forces – In-Flight					x	x	
PE109	Lightning of Other Aircraft/Vehicle				x			
PE110	Noise Interference				x	x	x	x
PE111	Brownout/Whiteout				x	x		
PE201	Seating and Restraints				x	x		x
PE202	Instrumentation and Sensory Feedback Systems				x	x		
PE203	Visibility Restrictions				x	x		
PE204	Controls and Switches				x	x		

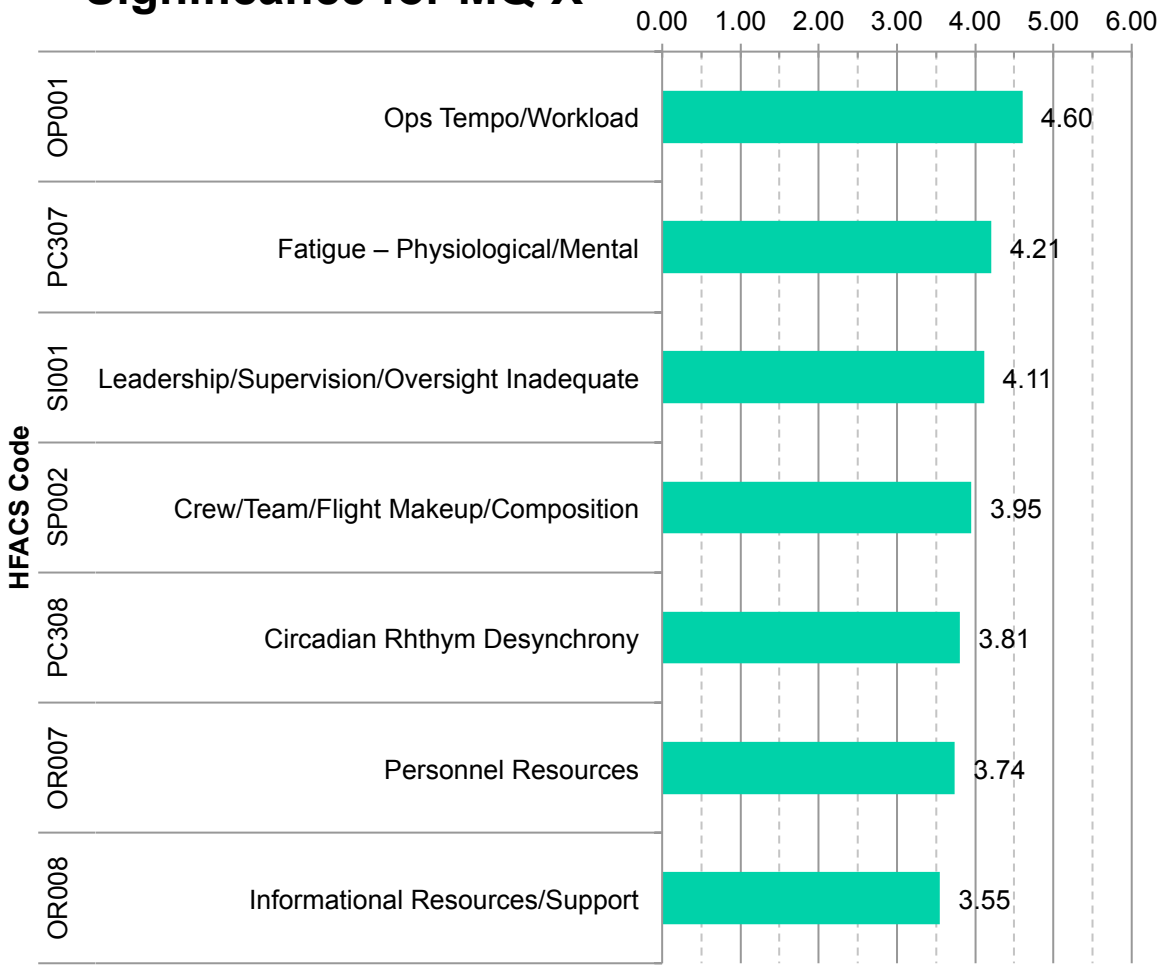
- **Formed though collaboration sessions with engineers, HF practitioners, and academics**
- **Presented to INCOSE HSI WG and feedback incorporated.**

5. Requirements Elicitation: MQ-X



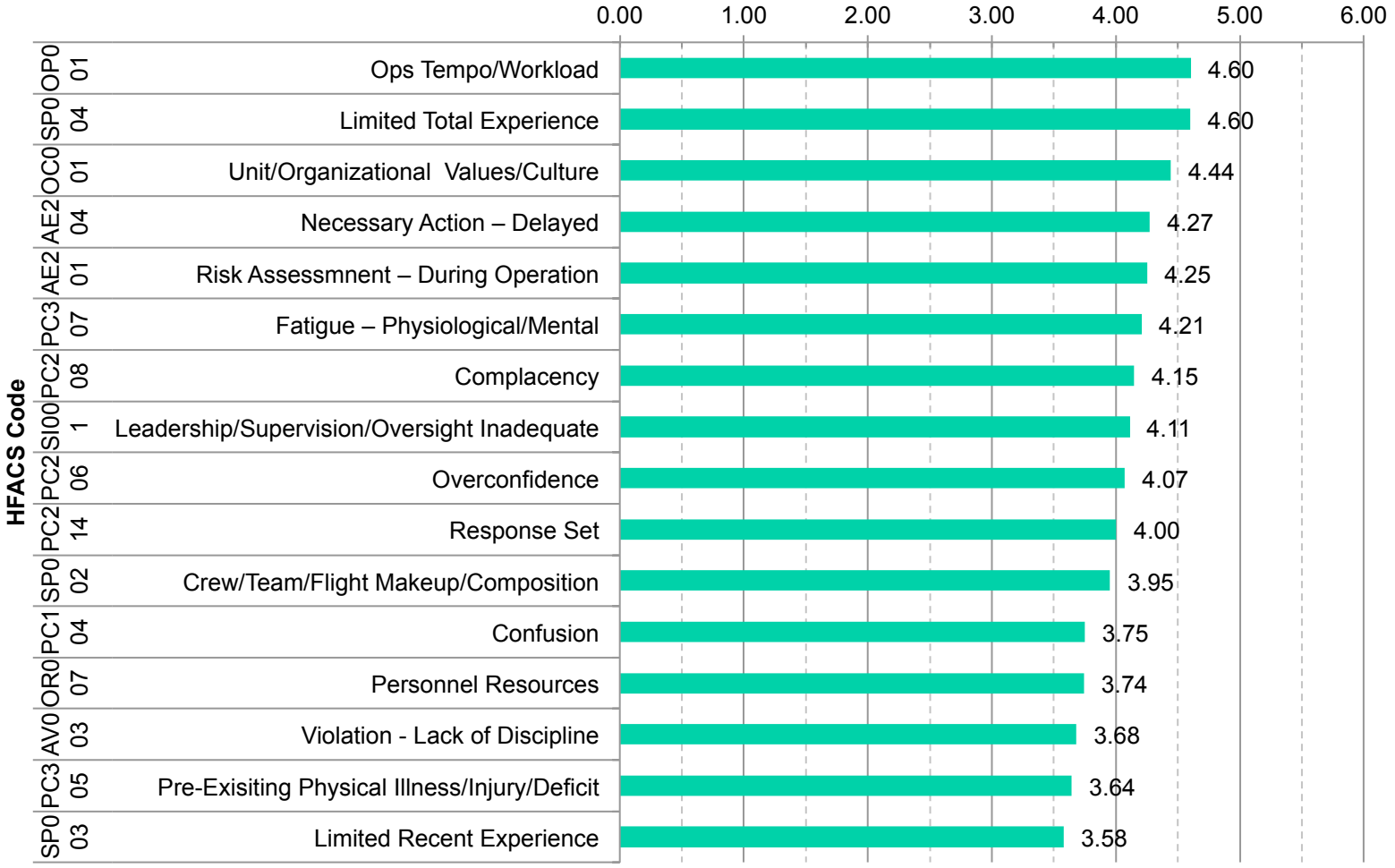
HFACS	Description	Related Domain(s)
OP003	Procedural Guidance/Publications	Training
SI003	Local Training Issues/Programs	Training
OR004	Acquisition Polies/Design Processes	Safety
PC102	Channelized Attention	Training, Human Factors
OP002	Program and Policy Risk Assessment	Safety
OP001	Ops Tempo/Workload	Human Factors, Manpower, Personnel
SP004	Limited Total Experience	Training, Personnel
OP004	Organizational Training Issues/Programs	Training
OC001	Unit/Organizational Values/Culture	Training, Personnel
PC508	Spatial Disorientation 1 Unrecognized	Human Factors

5. Requirements Elicitation: MQ-X



5. Requirements Elicitation: MQ-X

HSI Domain: Personnel
Significance for MQ-X



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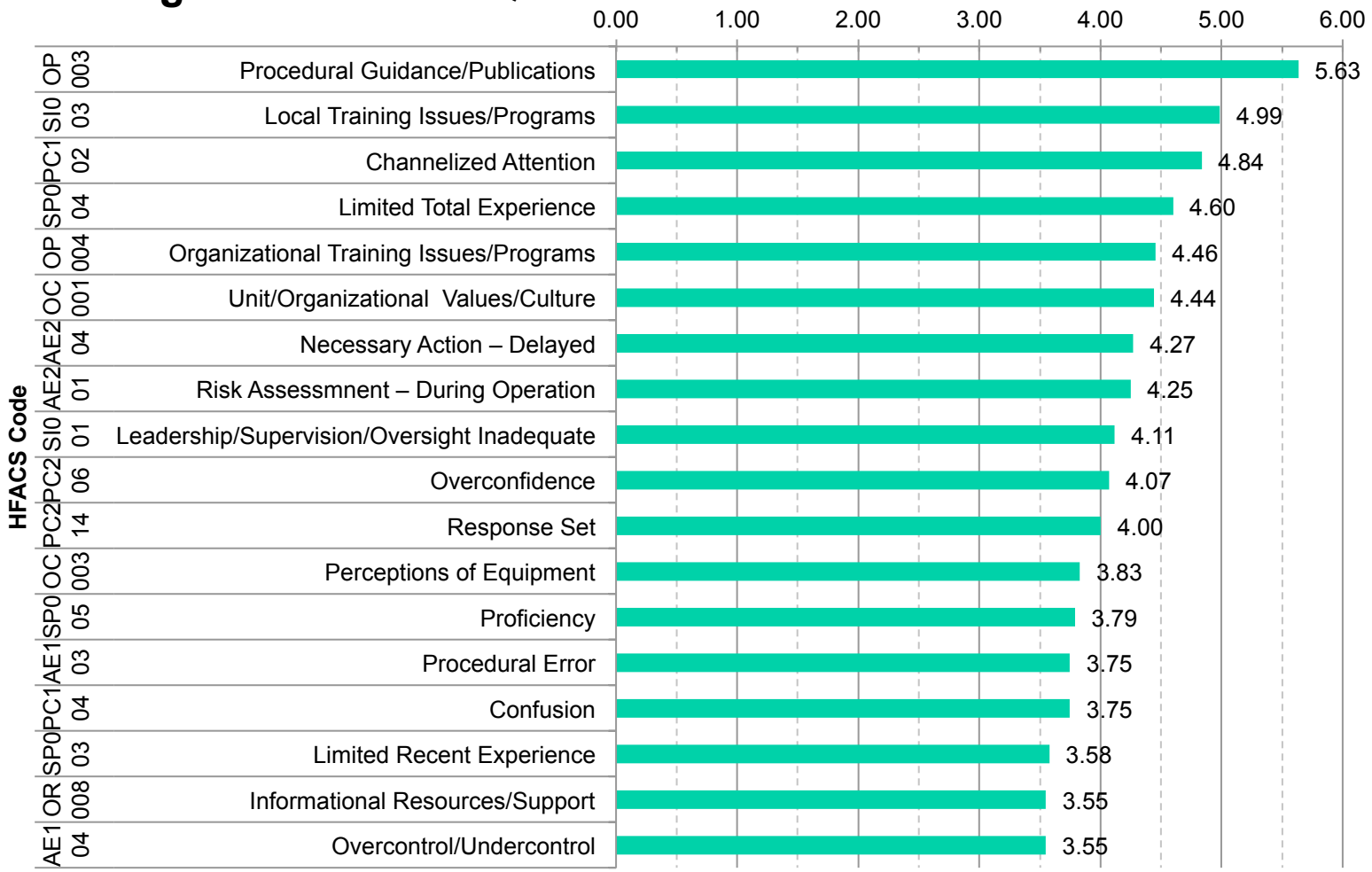
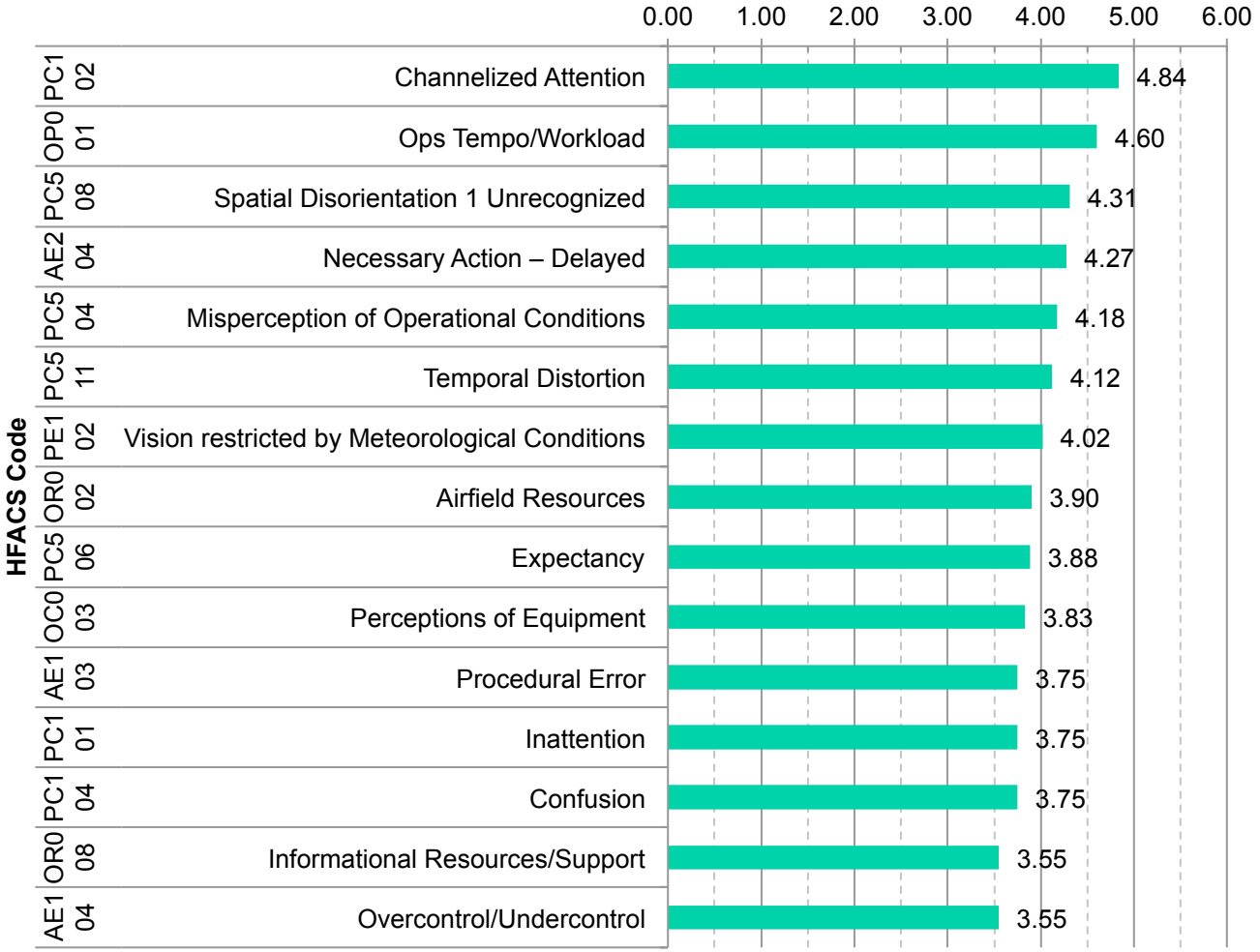


5. Requirements Elicitation: MQ-X



Summary

- **RELAAy is a bridge between the safety and SE community**

- **"Tunable" method tailored by:**
  - **Data set**
  - **Error taxonomy**
  - **Risk ratings**
  - **Similarity weighting**
  - **HSI mapping**

Conclusion

- **Research has established the importance of HSI in new system design**

- **Engineers must elicit and prioritize HSI requirements earlier in system development**

- **The RELAAy method analyzes legacy system mishaps involving human error as a causal factor**
  - **Identifies significant causal HFACS**
  - **Uses a proposed HFACS-HSI mapping**