The Evolution of Risk Mitigation in Flight Test for Complex Systems

A Brief History for Tomorrow

Enlightenment From 4 Decades

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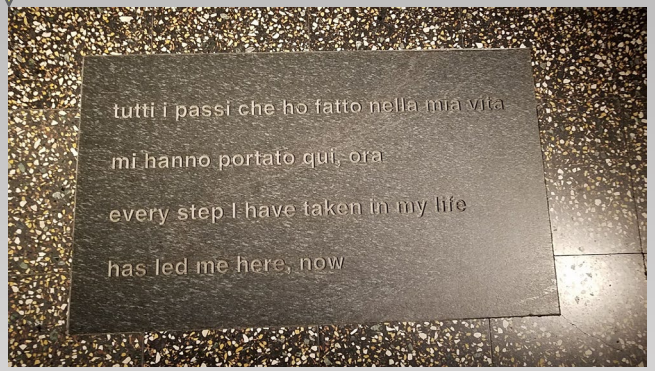
SFTE Fellow
Lockheed Martin Fellow (*Emeritus*)

My Journey…



F-35 Japan

F-16 Block 60

F-16 Super Viper

F-35

DT&E

F-16

Pilot Blamed for Deadly F-16 Crash

F-35 Italy

A-12 Avenger

India

Risk Awareness

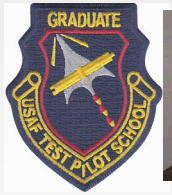
F-4 Phantom

ORACLE FTRT

F-14 Tomcat

MMRCA

STAMP/STPA



UK-Exchange

1978 1984 1988 1992 1995 2008 2012 2021

Ames Research Center NASA

AFLC

4950TH TEST WING

GENERAL DYNAMICS

LOCKHEED

UNITED STATES NAVY NAVY RESERVE

LOCKHEED MARTIN

The Experiences that Enlightened my Flight Safety Awareness

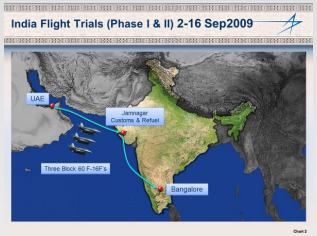
F-35 Japan

F-16 Super Viper

F-35 DT&E

India

F-35 Italy



Risk Awareness

MMRCA

STAMP/STPA

Pilot Blamed for Deadly F-16 Crash

January 4, 1994

1994 **2008** **2012** **2021**

MMRCA (India) Flight Demonstrations (Palmdale Calif)

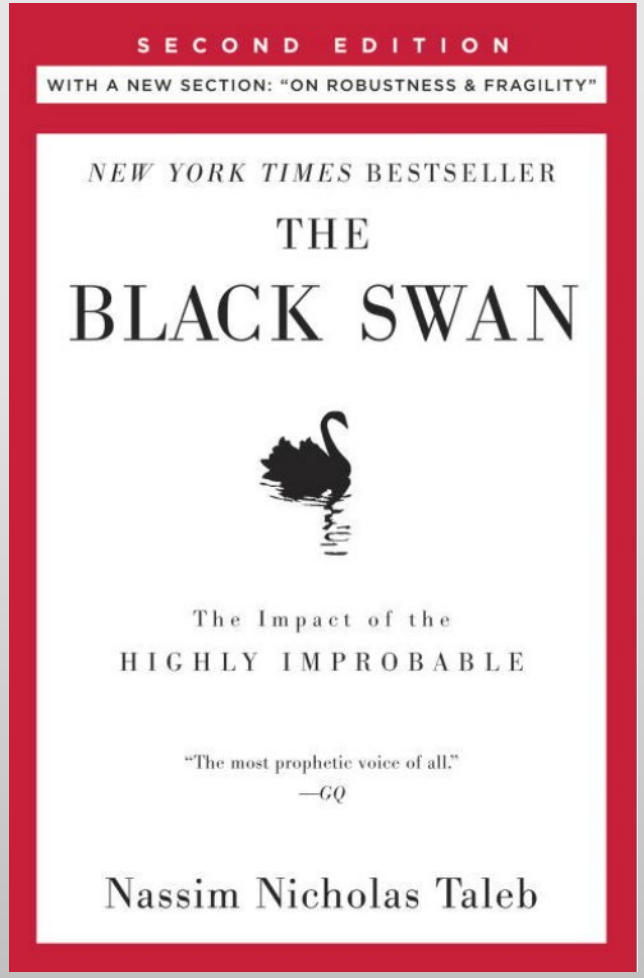
Traditional Risk Matrix is Not Sufficient

RISK ASSESSMENT MATRIX				
SEVERITY / PROBABILITY	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A)	High	High	Serious	Medium
Probable (B)	High	High	Serious	Medium
Occasional (C)	High	Serious	Medium	Low
Remote (D)	Serious	Medium	Medium	Low
Improbable (E)	Medium	Medium	Medium	Low
Eliminated (F)	Eliminated			

Figure 1: A standard risk matrix from MIL-STD-882E.

Can be Counterproductive

“Statistical science models can tell you something about normal events, but they cannot deal with unexpected, high-impact events.” Dr. Nassim Taleb



- A Surprise (to the observer)
- Major Impact
- Rationalized by Hindsight

"Fooled by Randomness"

"We don't understand the world as well as we think we do and tend to be fooled by false patterns, mistake luck for skills, overestimate knowledge about rare events (Black Swans), as well as human understanding, something that has been getting worse with the increase in complexity…"

Dr. Nassim Taleb – April 11, 2011, *Fortune*

4 *Strategies* for Mitigating Flight Test 'Black Swans' drawn from Dr. Nassim Taleb's "10 Principles"

1. No Incentives Without Disincentives
2. *<u>Everyone</u> Bears Some Responsibility*
3. *Every Captain should go down with every ship*
4. *Counter-balance complexity with simplicity.* Complex systems survive thanks to slack and redundancy

10 Principles for a Black Swan-proof World, Taleb, Financial Times…. http://www.fooledbyrandomness.com/tenprinciples.pdf

Growing Challenge - Complexity!

Systems

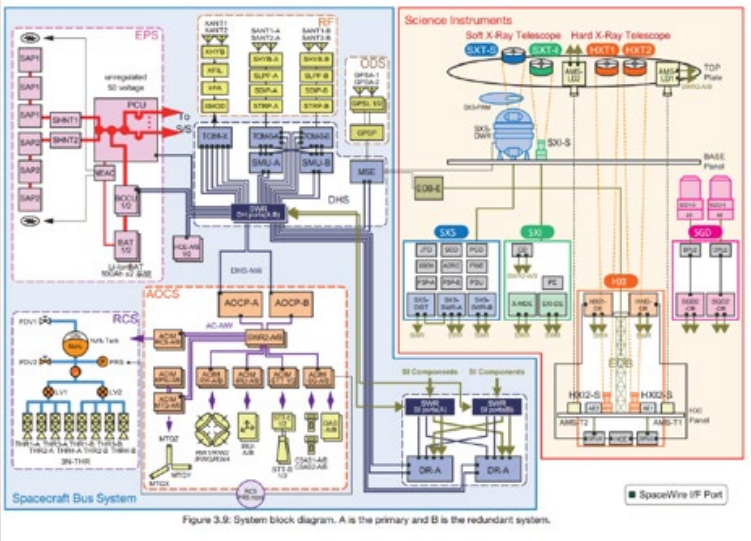
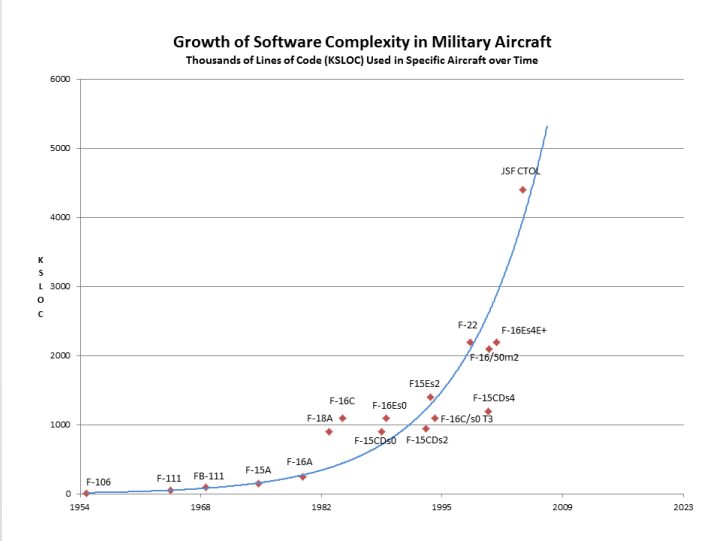
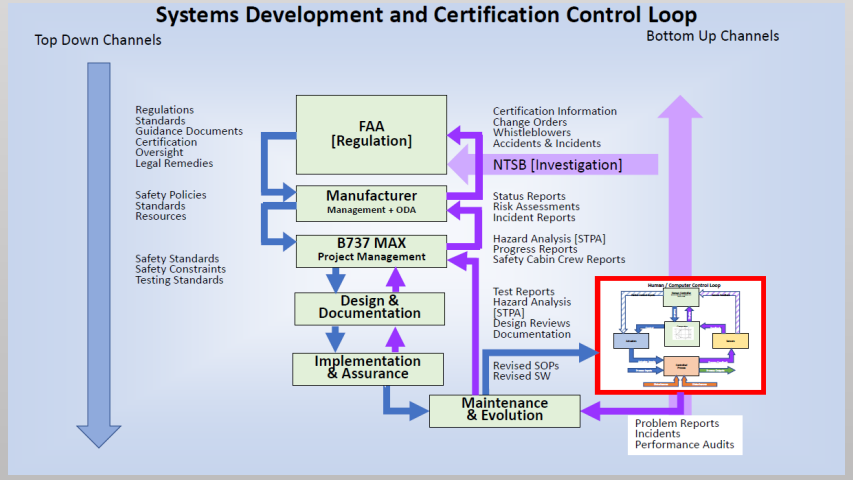


Figure 3.9: System block diagram. A is the primary and B is the redundant system.

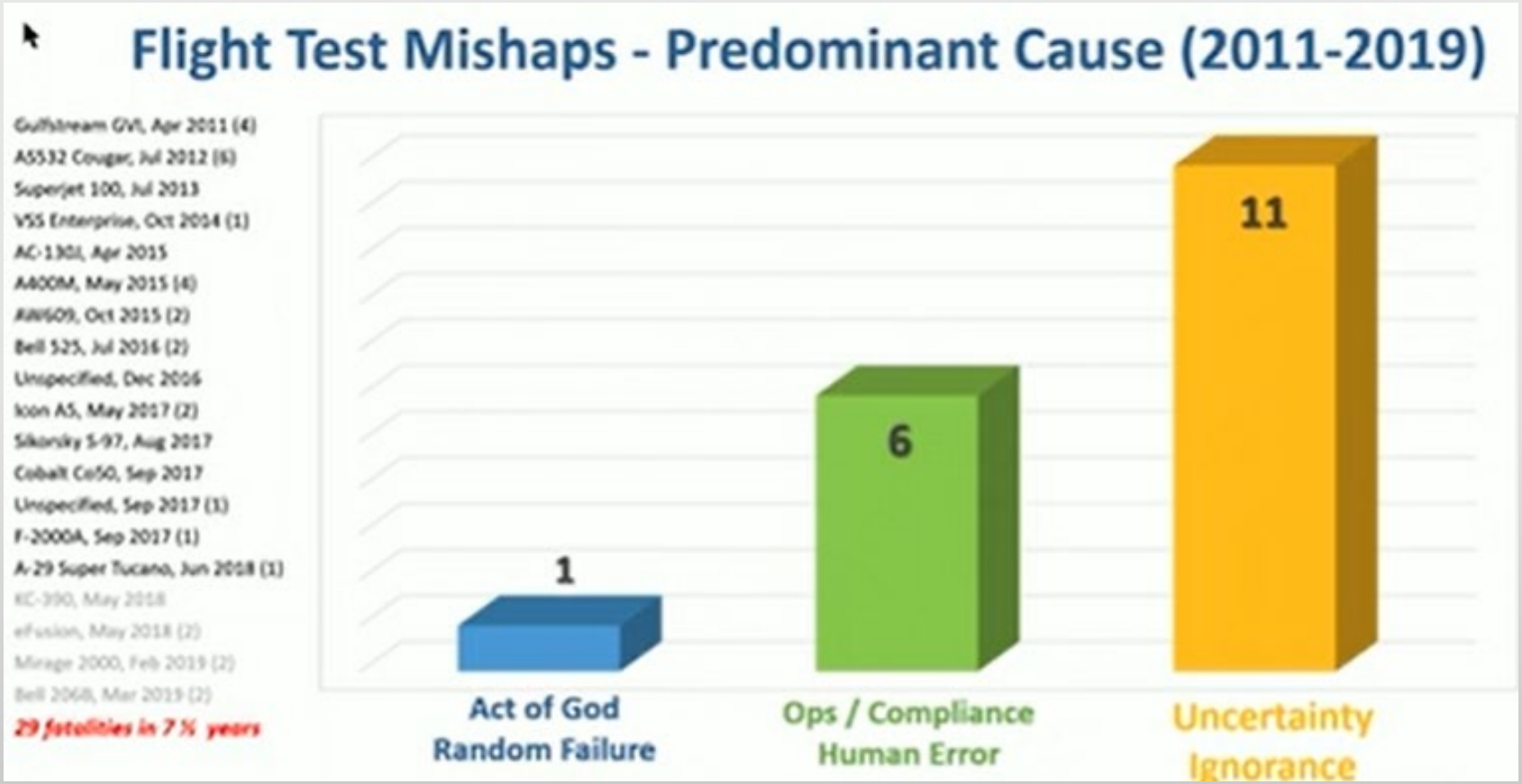
Software



Organizations (Processes)



Complexity Impact in Flight Test



Complexity Impact in the Operational World

Examples of Accidents Where Software Operated "As Designed"

Control Systems Operated Exactly as Designed!

Distracted pilot & flight control logic glitch

Asiana B777 – Auto-Throttle Doesn't Advance

Learjet 60–Computer Ignored Pilot Commands

The problem is that we are attempting to build systems that are beyond our ability to intellectually manage: Increased interactive complexity and coupling make it difficult for the designers to consider all the potential system states or for operators to handle all normal and abnormal situations and disturbances safely and effectively."

from *Engineering a Safer World by* Professor Nancy Leveson
Dir of MIT Partnership for Systems Approaches to Safety & Security

Barham & Hughes-"Why Flight Test Is Distinctively Complex"

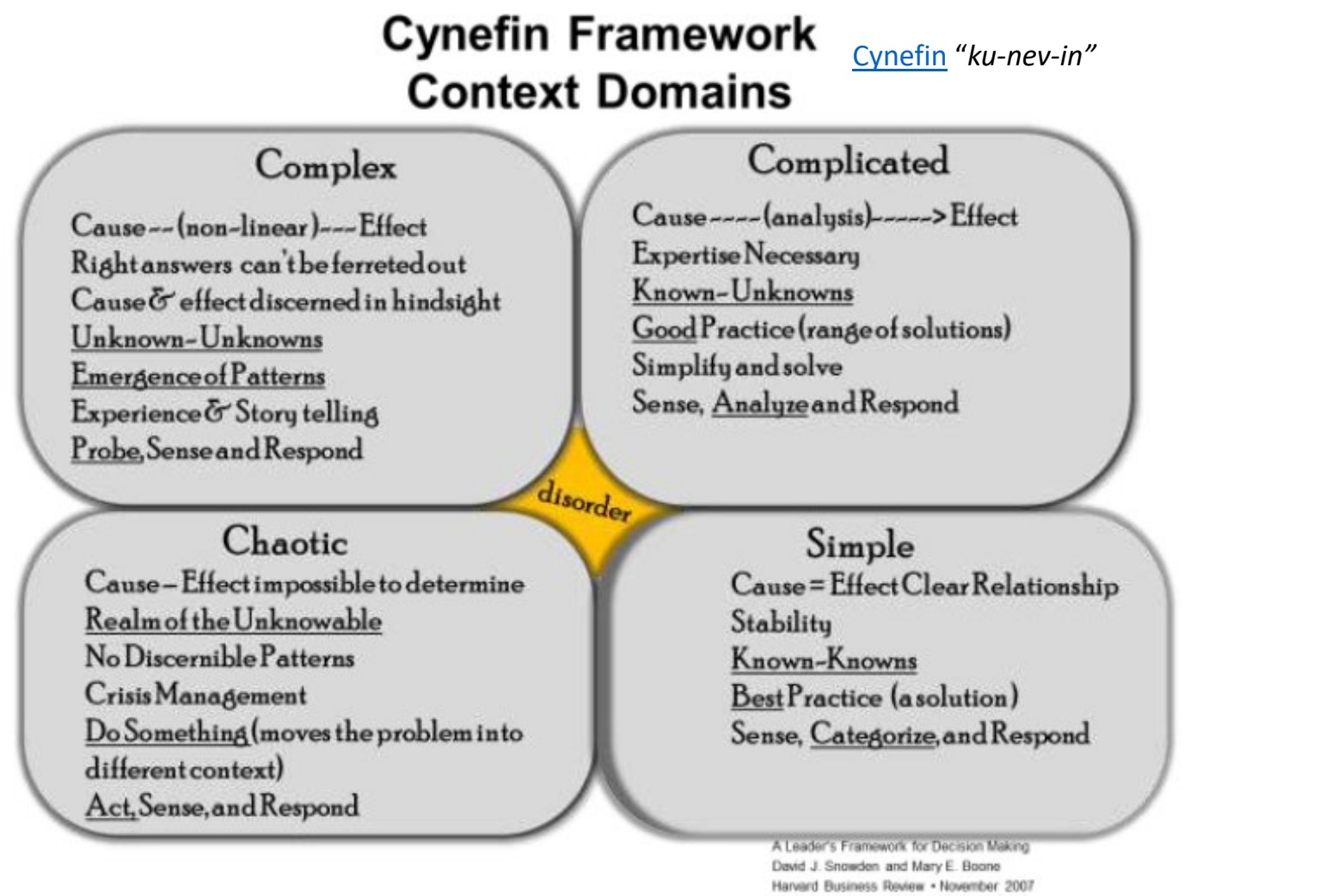


Figure 1 Cynefin Framework Context Domains

Employ Cynefin for Effective & Safer Flight Test Operations

Flight Test Operations Reside Mostly in the Complex Domain.

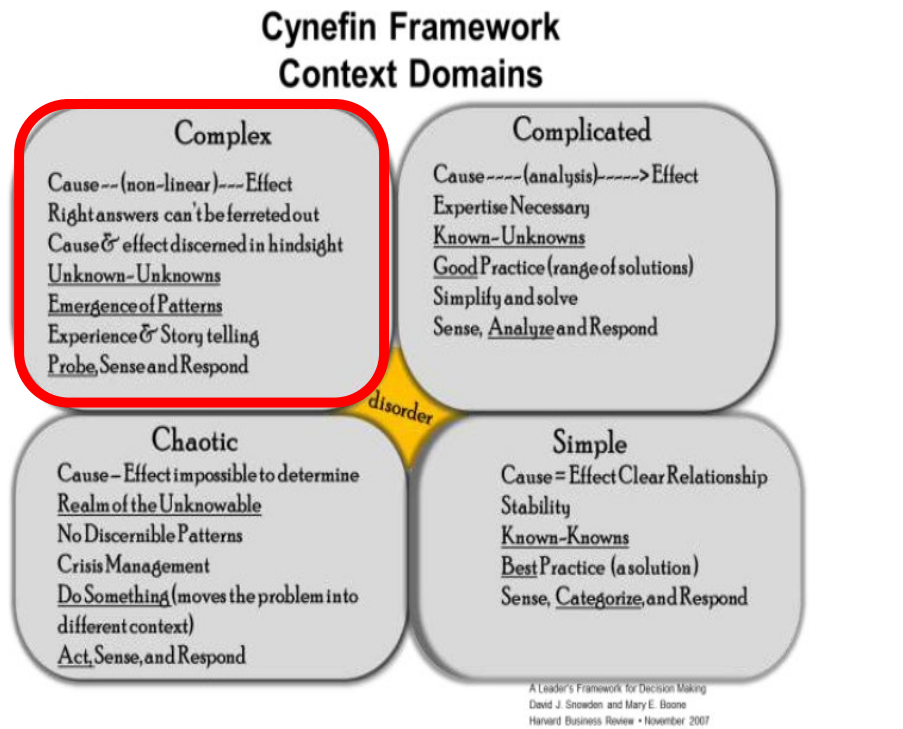


Figure 1 Cynefin Framework Context Domains

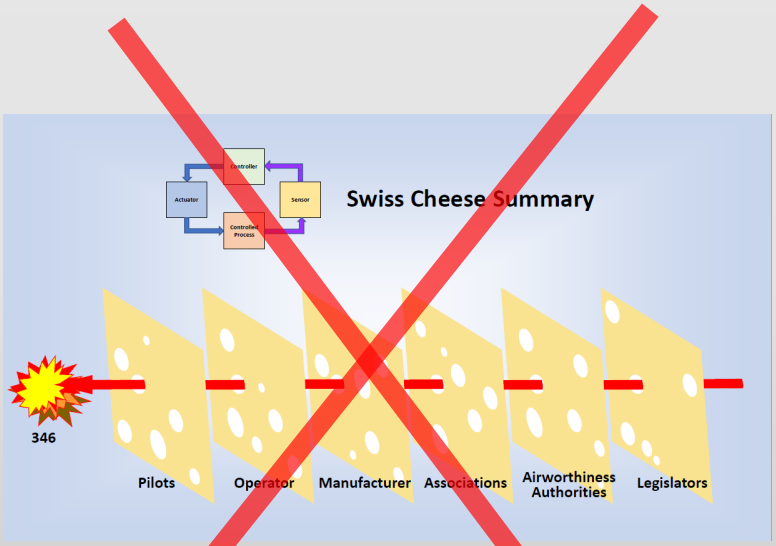
In the Complex Domain

Employ pattern recognition and principles vice analysis & rules.

Experiences, Storytelling, Mentoring & Airmanship are Key to Pattern Recognition

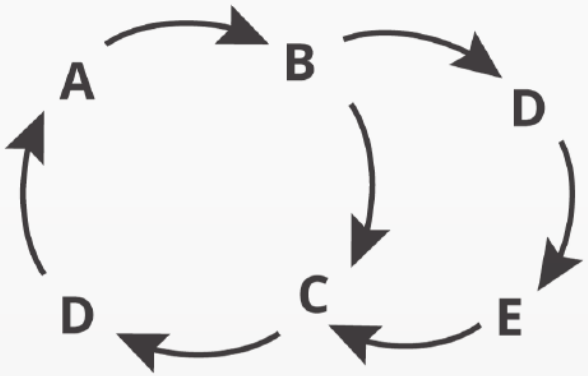
Recognize Engineers & Managers operate in different domains

Moving Safety Mindset from Linear “Event Oriented Thinking to Systems Thinking”



Systems Thinking

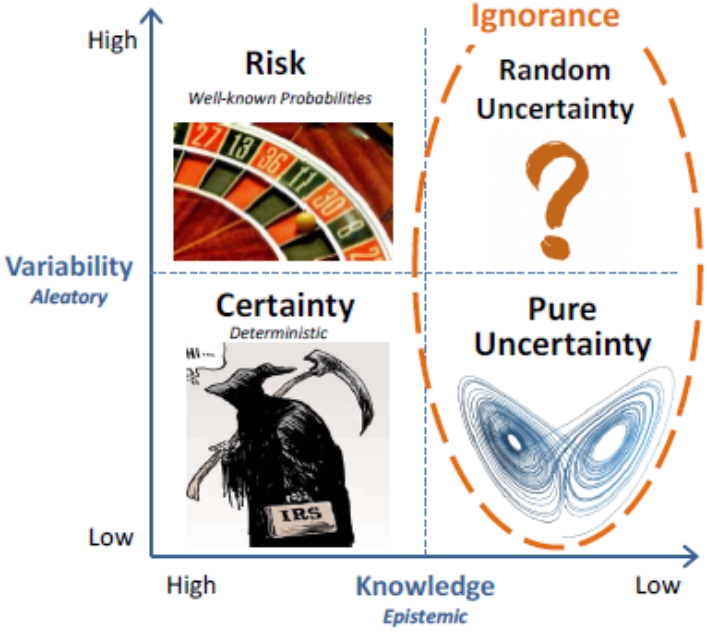
Thinks in loop structure



In systems thinking a system’s behavior emerges from the structure of its feedback loops. **Root causes** are not individual nodes. They are the forces emerging from particular feedback loops.

Created by Thwink.org

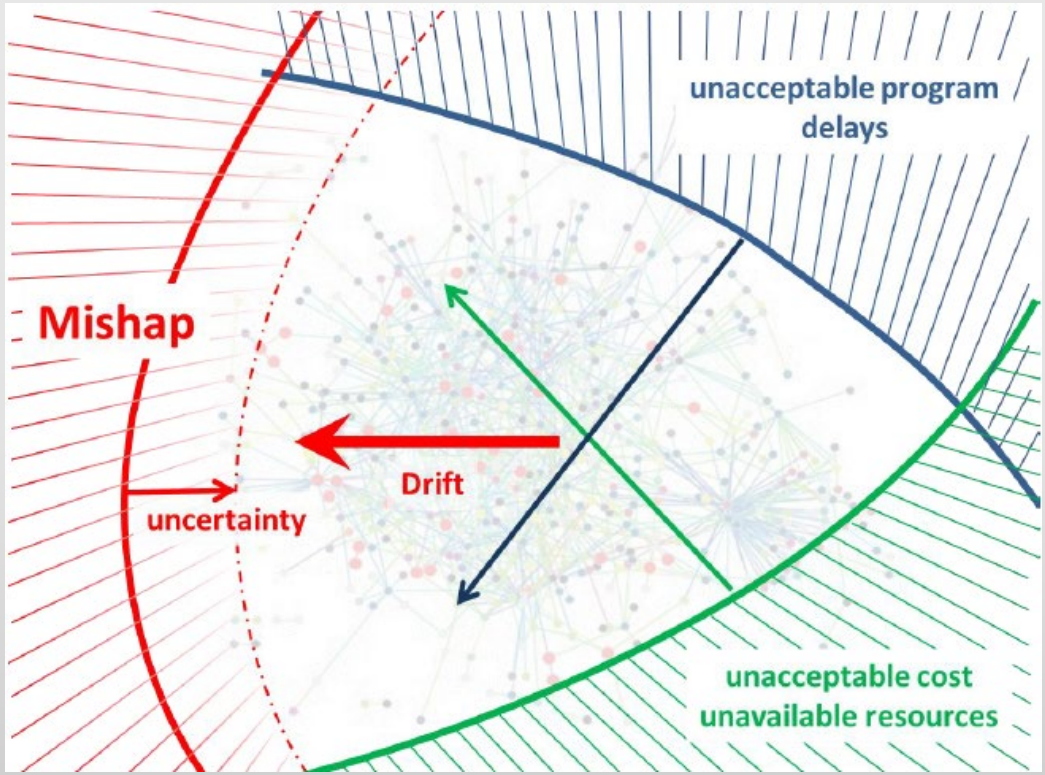
2018 Wickert - Risk Awareness: A New Framework for Risk Management



- 2 Factors Characterize Risk
- Understand domain you are operating in
- Be Wary of Probability Estimates
- Employ different strategies & tools based on domain
- **Knowledge is Control Parameter**

"Wickert, Douglas., "Risk awareness: A new framework for risk management in flight test." Proceedings to the SETP 62nd Annual Symposium, 2018.

Risk Awareness Emerges in Complex Systems and Organizations.



To cultivate risk awareness:

1) Identify and characterize the nature of the unknowns

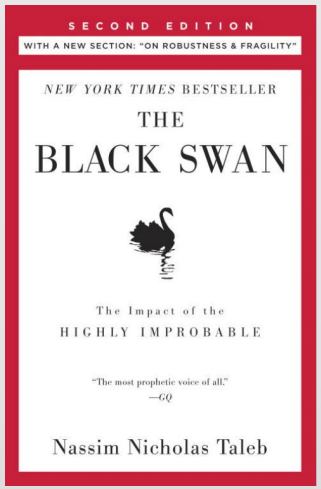
2) Reduce the reducible ignorance

3) Democratize safety decision making

4) Resist drift

"Wickert, Douglas., "Risk awareness: A new framework for risk management in flight test." Proceedings to the SETP 62nd Annual Symposium, 2018.

3 Approaches - Good But Insufficient



2007

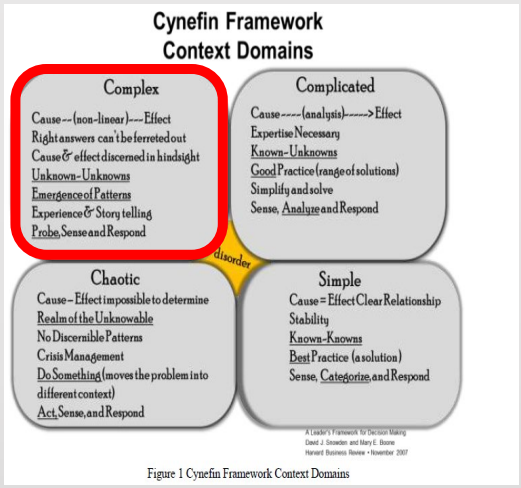
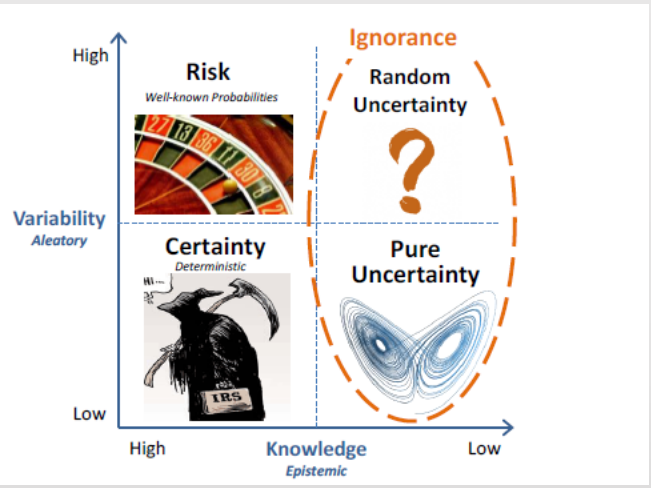


Figure 1 Cynefin Framework Context Domains

2016



2018

March Issue 20-03

Flight Test *Safety* Fact

Published for the Flight Test Safety Committee

In This Issue

Coffee with Ben and Jeff – A conversation about flight test safety and complexity

Massachusetts Institute of Technology
Partnership for Systems Approaches to Safety and Security

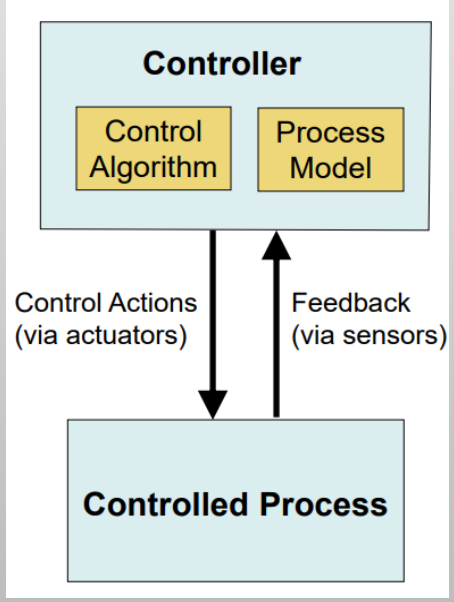
Dr. Nancy Leveson and Dr. John Thomas

- Safety Enhancements Focused on Complex, Software Intensive Systems
- STAMP Methodology (Systems Theoretic Accident Model & Process)
- Can Find Missing Requirements & Handle Unknown-Unknowns
- Prescriptive and "Human Centric"

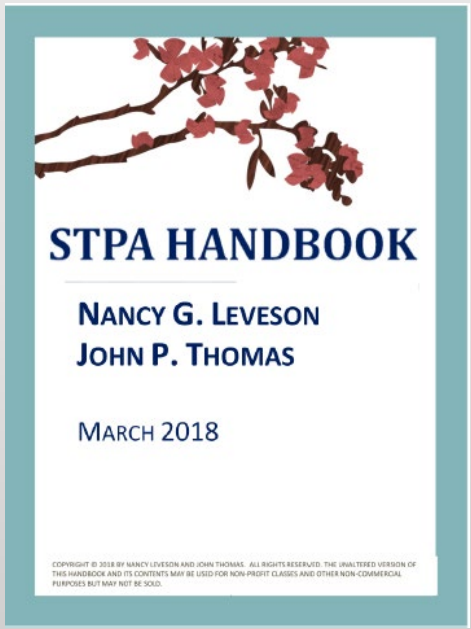
Key STAMP Tenets

For Complex Systems & Organizations:

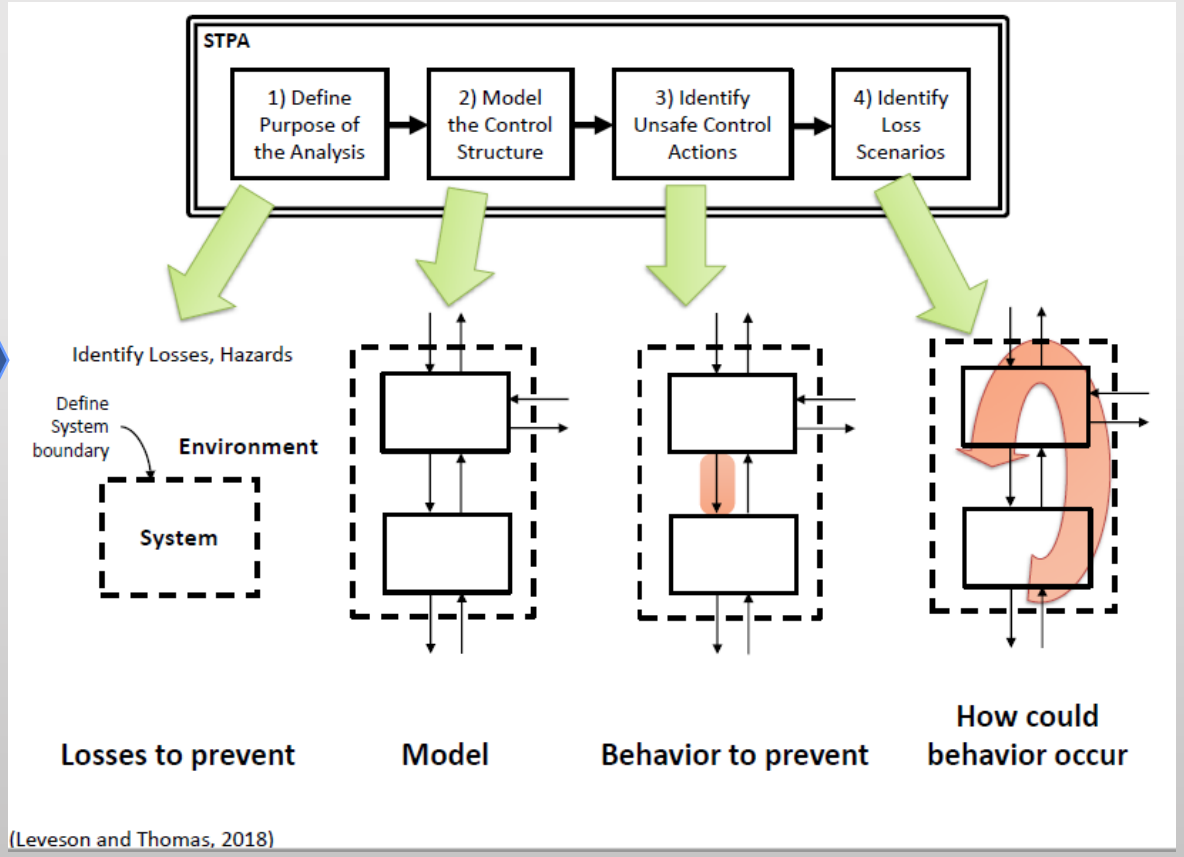
- Linear Causality Models Are Not Appropriate (Swiss Cheese)
- Using Probability to Assess Risk Can Undermine Safety
- Traditional Safety & Mishap Analysis Tools are Insufficient
- Pilot/Operator error can be a symptom, rather than the cause
- Component Failure is Not the Main Problem
- Address Safety as a Control Problem



STPA - A Rigorous 4 Step Model Based Systems Engineering Process to Identify & Mitigate Hazards



How-to guide mit.edu/psas



3 Pillars of Risk Awareness
Methodology & Tools
Culture
Tester Expertise & Influence

Flight Tester Expertise

"The traditional approach to training and management used with most design engineering disciplines and other program organizations is ineffective and perhaps dangerous when applied to the flight test discipline…"

Robert Barham & Starr Hughes, – *"A Different Perspective Why Flight Test Is Distinctively Complex"*
SFTE Tech Council Webinar, June 2016

Tester Influence Derives from Expertise

- ✓Holistic Training
- ✓Ongoing Professional Development
- ✓Competency Standards
- ✓Accredited Career Track

SFTE Guideline for Flight Test Engineer (FTE) Qualification

FTE Knowledge, Skills, & Abilities

Below list reflects FTE subjects & tasks from many organizations.
Some items do not apply to some organizations

	Recommended credit earning rate, limits, and minimum qualifying credits													
	Entry-Level				Credits earned via		Journeyman		Lead		Individual			
	2-yr tech school	2-yr degree	4-yr tech school	4-yr Dipl., Eng/Tech	Direct Exp. (incl. TPS) Credit Rate	Indirect Experience Credit Rate, Limit	Specialized Training via TPS, CEU, In-house Credit Limit (1 credit/day)	Qualifying Credits	Specialized Training via TPS, CEU, In-house Credit Limit (1 credit/day)	Qualifying Credits	Direct Exp	Indirect Exp	Specialized Training	earned credits
Write, review, or approve Risk Assessment& Management documents		x	x	x	.2/pla	0	0	1	0	2				
Present test plans at Technical Reviews.		x	x	x	.2/pla	0	0.2	1	1	2				
Conduct/Support Safety Review Boards or First Flight Readiness Review risk assesment.		x	x	x	.2/pla	0	0	1	1	2				

Expertise + Career Track => Influence

"*Flight Test Training is Expensive…but it is Good Business*"

Airbus VP for Flight Test - Patrick Du Ché

“It’s tough to make predictions, especially about the future” Yogi Berra

Real Time Model Based Analysis
Real Time Knowledge Envelopes
Less is More (Big Data)
Machine Learning Pattern Recognition
Augmented Reality Build-Ups
Virtual Reality Training
AI Assistants Control Room

Exciting Test Opportunities are Coming!
New Methodologies Offer the Potential for Safer and More Effective Flight Test.
Culture & Tester Influence are Foundational

Join Me on The Journey – Stay Humble - And Thank you!

Selected References
Contact Jeff Canclini on LinkedIn if Problems Accessing

Test Safety, Professional Expertise, and Productivity in Flight Test Canclini, SFTE India Symposium Feb 2022 (a deeper dive into this presentation with a comprehensive list of references and links)

Edwin Snowden Explains the Cynefin Framework

Why Flight Test Is Distinctively Complex Barham & Hughes

Risk Awareness: A new framework for Risk Management in Flight Test Wickert

Introduction to STPA MIT Partnership for Safety and Security

FTSC Safety Fact 20-03- "A Conversation with Ben and Jeff"

FTSC Safety Fact 20-03 Editor Mark Jones on the Promise & Peril of Big Data

"Outcome-based Framework For Online Model Validation And Risk Awareness" Jurado & McGehee, 2022 SFTE Symposium & 2021 SETP Symposium