MH 370: STPA Supporting Possible Improvements in Air-Ground Tracking & Communication Systems

Lucas STEPHANE

Assistant Professor

Florida Institute of Technology

PhD Human Centered Design

MS Experimental Psychology

MS Business Intelligence

March 24, 2015

MIT, MA

MH370 highlights

Current status

- **Search still ongoing** (26 countries, hundreds of millions of USD so far…)

- **Uncertainty about**
  - What happened
  - Why/How it happened
  - **Where is the A/C**
    - **Unknown underwater area**

- **Unacceptable Losses**
  - **ALARA** (As Low As **?Reasonably?** Acceptable)
    - Human Losses (239 Passengers & Crew)
    - Aircraft
    - Impacts on
      - Victims' families & friends
      - Airline…

  - ***Unacceptable to have an aircraft missing*** *(in the 21st century…)*

MH370 highlights

ICAO Annex 13: Factual Information – 03.08.2015

http://www.mh370.gov.my/index.php/en/media2/transcript/category/13-mh370-safety-investigation-public#

Timeline (selected events):

- 0119:30 MYT: **last verbal communication**
- 0121:13 MYT: **last Secondary Radar signal around IGARI**

- **Slight variations in speed, altitude & heading after IGARI**
- Between VAMPI & MEKAR it followed route N571…

- 0222:12: **lost by military radar after MEKAR**

- 0632 MYT: **1st DETRESFA message for Search and Rescue: 5h11min LATER**
- 0819 MYT: **last SATCOM received from MH370 by Inmarsat IOR I3**
- 1130 MYT: **first SAR aircraft took off**

Last communications: Appendix 1.18 (E, F…)

Other

- **SSFDR ULB battery: expiry date: December 2012**
- **SSCVR ULB battery: expiry date: June 2014**

MH370 highlights

ICAO Annex 13: Factual Information – 03.08.2015

http://www.mh370.gov.my/index.php/en/media2/transcript/category/13-mh370-safety-investigation-public#

	No SSR radar symbol on the Flight Plan Route
	SSR Transponder was not serviceable
9	3.2Nm after passing IGARI at 1721:13 UTC [0121:13 MYT]. The radar position of MH370 dropped off
8	MH370 Mode S symbol dropped off at 1720:36 UTC [0120:36 MYT]
7	MH370 over waypoint IGARI at 1720:31 UTC [0120:31 MYT]
6	`KL ATCC transferred MH370 to HCM ATCC at 1719:26 UTC [0119:26 MYT], 8.6 Nm to waypoint IGARI. MH370 acknowledged KL ATCC instruction to contact HCM ATCC with '*GOOD NIGHT MALAYSIAN THREE SEVEN ZERO*' at 1719:30 UTC [0119:30 MYT]
	MH370 reported again maintaining FL350 at 1707:56 UTC [0107:56 MYT]
5	MH370 maintaining FL350 at 1701:17 UTC [0101:17 MYT]
4	MH370 climbing to FL350 at 1650:11 UTC [0050:11 MYT]
3	MH370 climbing to FL250 at 1647:03 UTC [0047:03 MYT]
2	MH370 climbing to FL180 at 1643:01 UTC [0043:01 MYT]
1	Lumpur Tower cleared take-off at 1640:37 UTC [0040:37 MYT] and MH370 departed at 1642 UTC [0042 MYT]

Figure 1.1A - Chronological Sequence of Events of Disappearance of MH370

MH370 highlights

ICAO Annex 13: Factual Information – 03.08.2015

http://www.mh370.gov.my/index.php/en/media2/transcript/category/13-mh370-safety-investigation-public#

1	P3362 : Appeared at 1730:37 UTC [0130:37 MYT]
2	P3362 : Coasted at 1737:12 UTC [0137:12 MYT] Dropped at 1737:22 UTC [0137:22 MYT]
3	P3401: Appeared at 1738:56 UTC [0138:56 MYT]
4	P3401 : Coasted at 1744:42 UTC [0144:42 MYT] Dropped at 1744:52 UTC [0144:52 MYT]
	SOURCE OF INFORMATION: FR0M THE MILITARY
5	P3415 : Appeared at 1747:02 UTC [0147:02 MYT]
6	P3415 : Coasted at 1748:29 UTC [0148:29 MYT] Dropped at 1748:39 UTC [0148:39 MYT]
7	P3426 : Appeared at 1751:45 UTC [0151:45 MYT]
8	P3426 : Coasted at 1752:25 UTC [0152:25 MYT] Dropped at 1752:35 UTC [0152:35 MYT] P3426 last seen on radar display approximately 6Nm South of Penang
9	The primary target (military radar) appeared to track west-northwest direction joining RNAV Route N571 at waypoint VAMPI then to 10Nm north MEKAR
10	The primary target ended at 10Nm after MEKAR at 1822.12 UTC [0222.12 MYT]

Figure 1.1B – Diversion from Filed Flight Plan Route (not to scale)

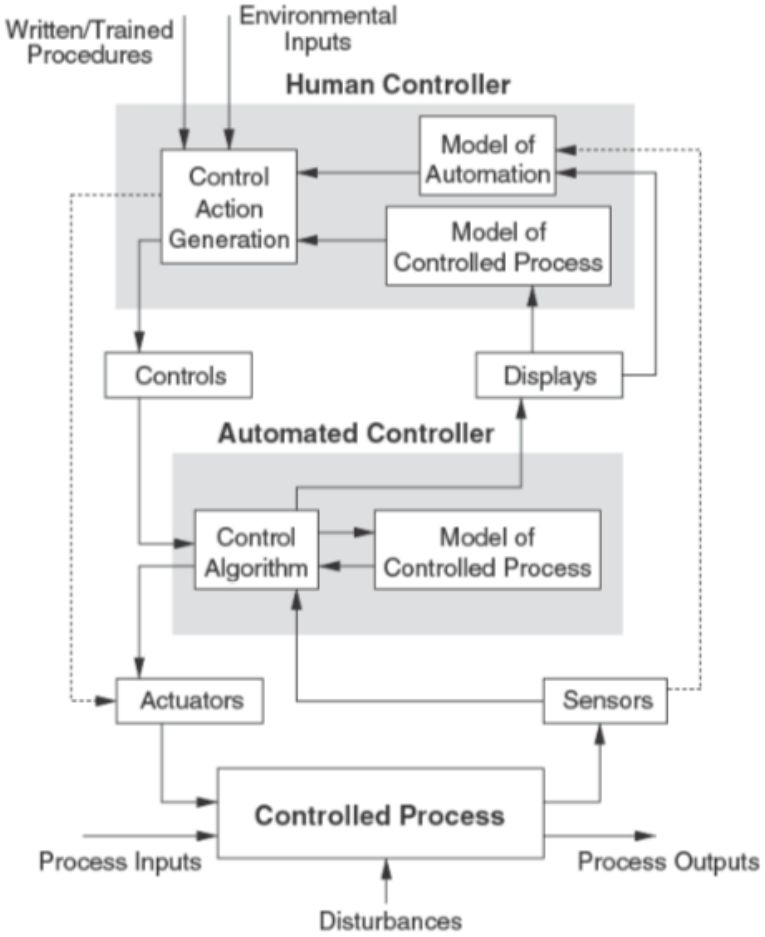
MH370 highlights: STPA

System Theoretic Process Analysis (STPA)

Leveson, 2011

- Identify the potential for inadequate control actions leading to hazardous states
  - Action is **not provided**
  - **Unsafe action** is provided
  - **Safe action** is provided:
    - too soon
    - **too late**

- Determine how each potentially hazardous control actions could occur…

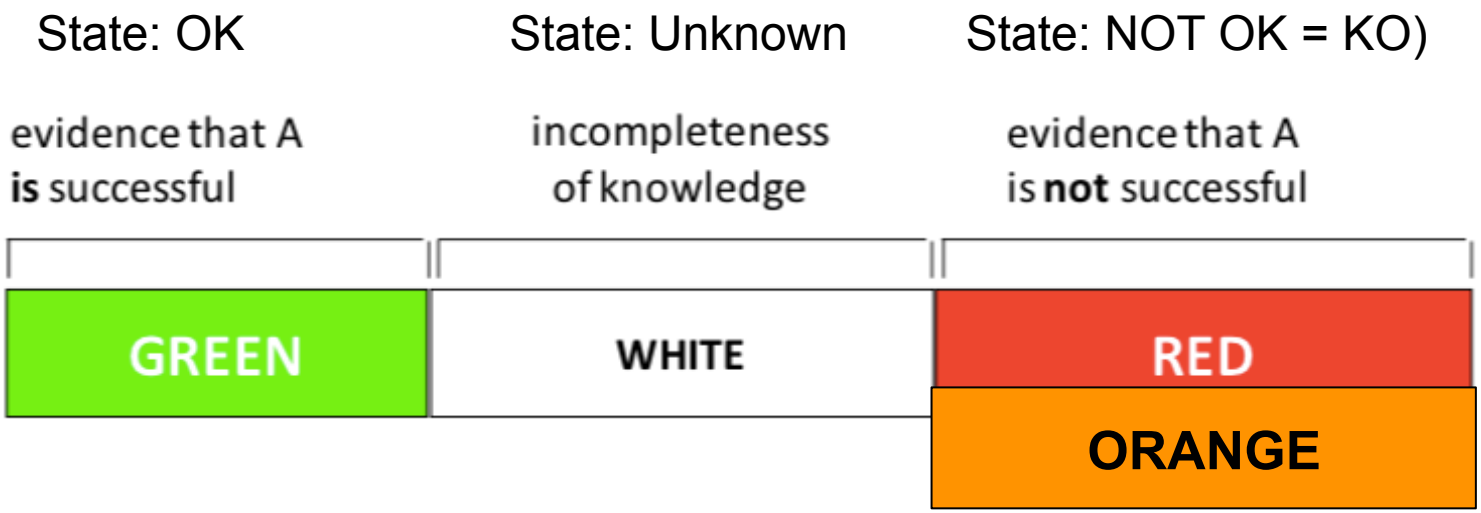


MH370 highlights: STPA

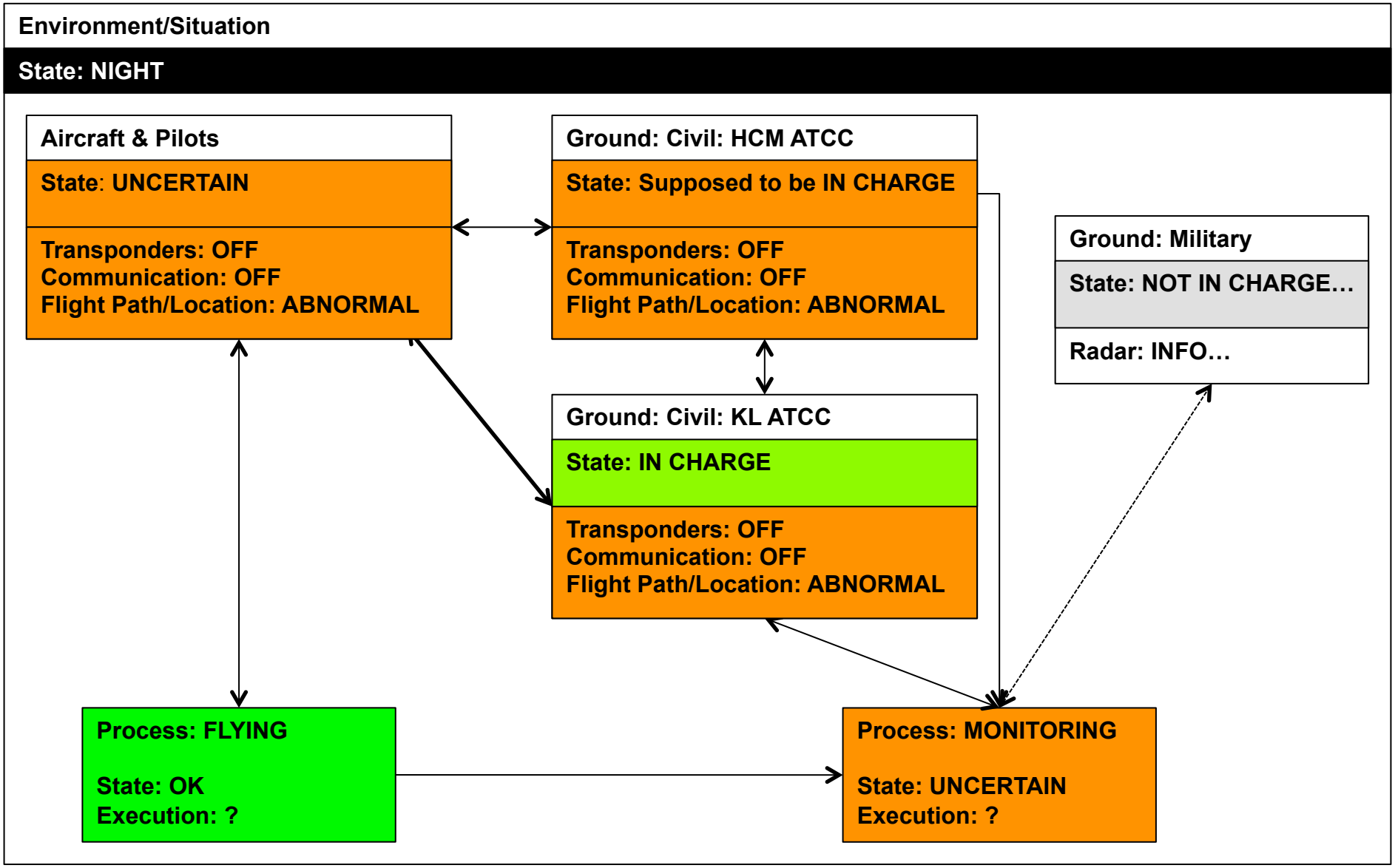
Color Codes: "Italian Flag"

Sir Beddington et al., 2011

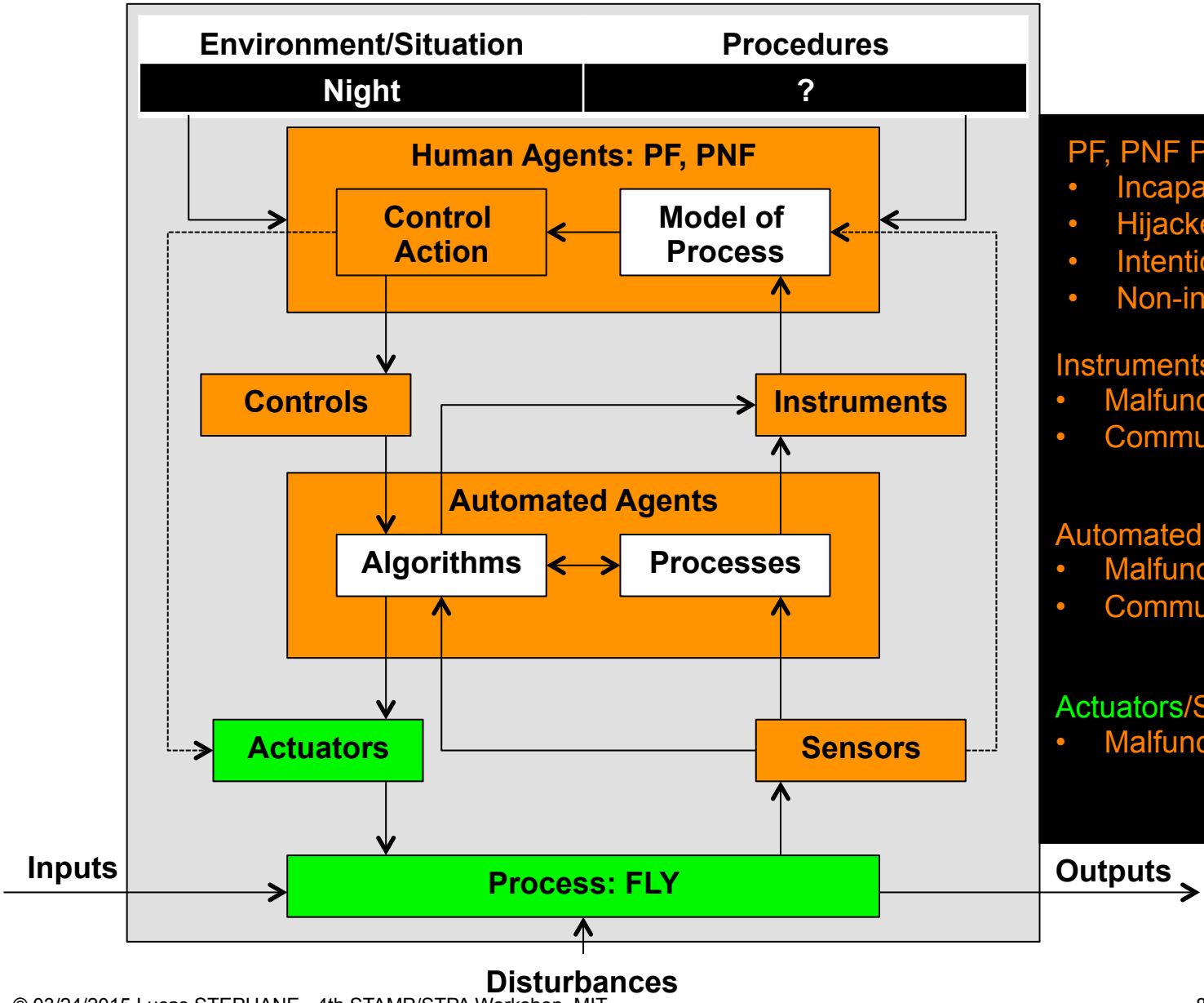
- Proposed for **categorizing levels of certainty/uncertainty of system states** in STPA
- **ORANGE used instead of RED since evidence is not yet 100%...**



MH370 highlights: STPA



MH370 highlights: STPA



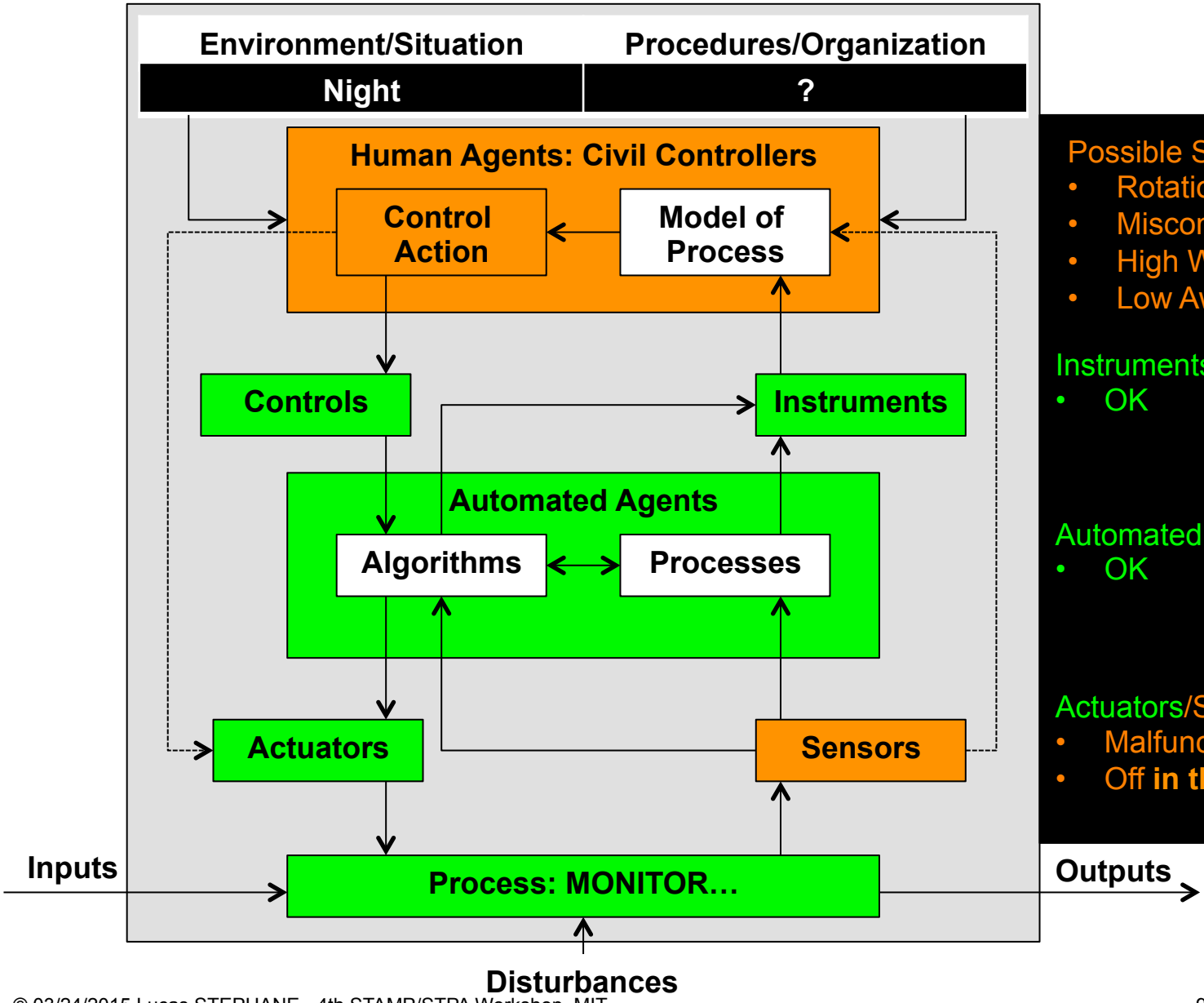
PF, PNF Possible State(s):
- Incapacitated?
- Hijacked?
- Intentional?
- Non-intentional?

Instruments Possible State(s)?:
- Malfunction?
- Communication off?

Automated Agents Possible State(s)?:
- Malfunction?
- Communication off?

Actuators/Sensors Possible States?:
- Malfunction?

MH370 highlights: STPA



Possible State(s)?:
- Rotation?
- Miscommunication?
- High Workload?
- Low Awareness?

Instruments State(s):
- OK

Automated Agents State(s):
- OK

Actuators/Sensors Possible States?:
- Malfunction **in the A/C?**
- Off **in the A/C?**

Advanced Tracking & Communication: Civil Aviation: State of the Art (US)

ADS-B (Automatic Dependent Surveillance-Broadcast)
www.faa.gov/nextgen/programs/adsb/general/

"With ADS-B, both pilots and controllers can see radar-like displays of traffic –[…] next to real time and do not degrade with distance or terrain."

- **Gains in safety, capacity, and efficiency as a result of moving to a satellite-based system**
- **Air-to-air surveillance**
- **Surveillance to remote or inhospitable areas that do not currently have coverage with radar**
- **Real-time traffic & aeronautical information in the cockpit**

Advanced Tracking & Communication: Civil Aviation: State of the Art (US)

CATMT (Collaborative Air Traffic Management Technology) WP2 & WP3
www.faa.gov/nextgen/programs/catmt/

WP3

- **Collaborative Information Exchange (CIX) – increased situational awareness and improved constraint prediction** by the incorporation of data made available via System Wide Information Management (SWIM) mechanisms…

Data Comm (Data Communications)
www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/atc_comms_services/datacomm/general/

- First phase of the transition from the current analog voice system to an International Civil Aviation Organization (ICAO) compliant digital system
- **Introduction of air/ground trajectory automation capabilities […] that depends on efficient data communications between aircraft and air traffic management**

Advanced Tracking & Communication: Civil Aviation: State of the Art (US)

NVS (NAS Voice System)
www.faa.gov/nextgen/programs/nvs/

- **Voice capability which supplements data communications for tactical situations and emergencies,** operating in controlled airspace
- **Air-to-ground voice communication is no longer limited by geographical facility boundaries**

Weather
www.faa.gov/nextgen/programs/weather/

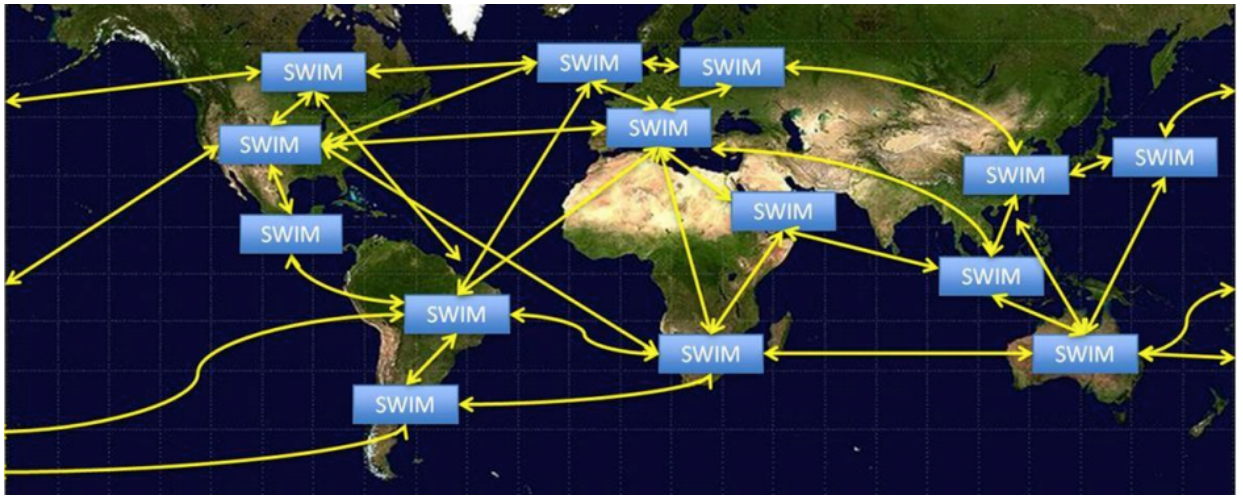
- NextGEN Weather Processor (NWP)
- Aviation Weather Display
- Common Support Services via SWIM

Advanced Tracking & Communication: Civil Aviation: State of the Art (US)

SWIM (System Wide Information Management)
www.faa.gov/nextgen/programs/swim/overview/

- **Separation of information provision & consumption for allowing number and nature of the consumers to evolve through time**
- **Loose system coupling**
- **Uses publicly available open standards**
- **The use of Service Oriented Architecture (SOA)** concepts within the design of a suite of **interoperable web-services**

- Promotes **International Harmonization** (Ngo, 2014)



Chen, 2014

Advanced Tracking & Communication: Civil Aviation: State of the Art (US)

SWIM (System Wide Information Management)
FAA, 2015

SWIM infrastructure allows more **efficient data sharing** among aviation partners

Two major SWIM features:

1. SWIM **streamlines connections** among different data systems **so users can access multiple systems through one connection**
2. SWIM **translates data from different systems into standard data formats**, supporting collaboration among industry and governments (US & International)

- **Global Exchange Models**
  - **FIXM** (Flight Information Exchange Model)
  - **WIXM** (Weather Information Exchange Model)
  - **AIXM** (Aeronautical Information Exchange Model)

- **Traffic Flow Management System**: provides subscribers with **Aircraft Situation Display to Industry (ASDI)** data access to traffic flow information

Advanced Tracking & Communication: Civil Aviation: State of the Art (US)

DOT/FAA: Aviation Rulemaking Advisory Committee - 03.20.2014 Meeting
www.faa.gov/regulations_policies/rulemaking/committees/documents/media/arac.meeting.minutes.03.20.2014.pdf

March 30, 2014

Paul Hudson (Aviation Consumer Action Project – ACAP)

"Mr. Hudson stated a tasking should include issues related to the MH370 incident, specifically **pilots' ability to avoid tracking by turning off transponders**.

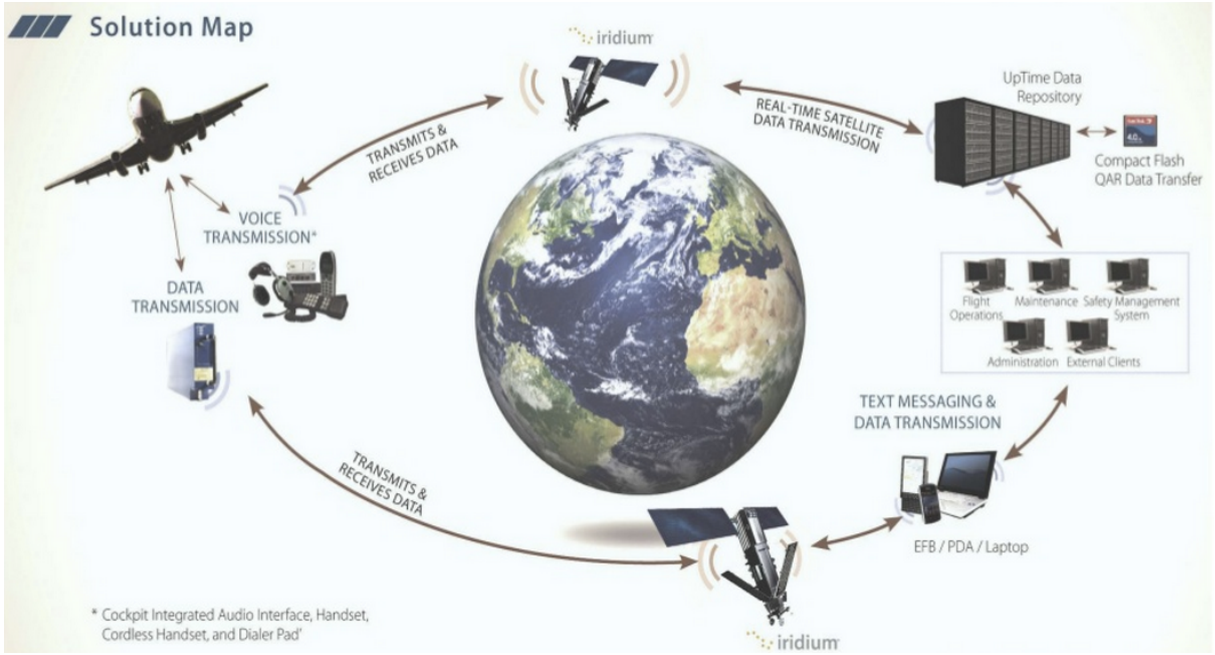
He explained current black box technology is dated, and **the industry should implement new data streaming capabilities in black boxes** to avoid negative repercussions." (p. 8)

Advanced Tracking & Communication: Civil Aviation: State of the Art (Canada)

FLYHT Stream

flyht.com/investors/videos/

- Automated Flight Information Reporting Systems (AFIRS)
- **Real-time 'virtual black box' emergency data streaming** activated by pilots, ground or triggered automatically by flight events
- **Air-Ground voice & text messages**
- Uses the **Iridium satellite system** infrastructure
- 64 units (60 for 12 Chinese companies; 4 in the US – 2 military, 2 commercial…)



FLYHT, **December 2014**

Advanced Tracking & Communication: Civil Aviation: State of the Art (Canada)

STAR In Flight Monitoring System (ISMS)

www.star-navigation.com/product/StarISMS

- **Online Remote Aircraft Safety Monitoring = 'virtual window' into aircraft**
- **Early warning system**
- **Instant Alert Notifications**
- **Transmits up to 3000+ Parameters per Minute** (depending on bandwidth): more than twice compared to MH370 SSFDR…
- Universal Access via Internet (anytime)
- Stand-Alone System or 24/7 Star Monitoring

STAR Airborne Data Service (ADS)

www.star-navigation.com/service/StarADS

- Real Time FOQA / FDM / MOQA and End of Flight (EOF) Analysis reports
- Secure SatCom transmission
- **Real time satellite global coverage from pole to pole**
- **Emergency data transmission display** for DFDR parameter and Emergency streamed position reports (SPR)

Advanced Tracking & Communication: Civil Aviation: State of the Art (International)

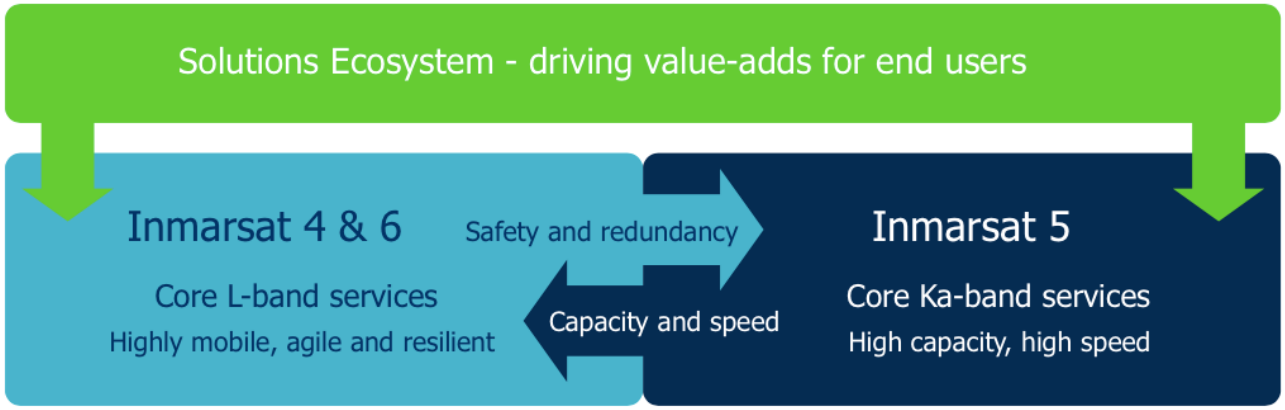
Inmarsat (Colledge & Ibnyahya, 2014)
www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/ato_intl/documents/cross_polar/cpwg18/cross%20polar%20wg18_inmarsat%20update%20dec%202014.pdf

ADS-C (Automatic Dependent Surveillance-Contract)

"Since the tragic disappearance of MH370, Inmarsat has been working with our Distribution Partners (including SITA and Rockwell Collins/ARINC), and a number of other industry partners to assist in defining solutions for aircraft flight tracking"

Need for an industry wide solution:
- **Locate aircraft** more systematically & accurately
- **Increase reactivity in case of abnormal route deviation or event**

"**Inmarsat is working with its partners to offer a Basic Tracking ADS-C message for free, every 15 minutes**"



Advanced Tracking & Communication: Civil Aviation: State of the Art (International)

Inmarsat + Qatar Airways

www.runwaygirlnetwork.com/2015/01/07/qatar-airways-signals-intent-adopt-black-box-streaming/

January 7, 2015

"Inmarsat – whose SwiftBroadband aeronautical service supports inflight Wi-Fi on Qatar's **Boeing 787s** and now the **A350** – is known to be offering a **'black box in the cloud' service, under which – on the back of certain defined trigger events (such as an unapproved course deviation) – historic and real-time flight data recorder and cockpit voice recorder information can be streamed off an aircraft to defined aviation safety recipients.**"

Advanced Tracking & Communication: Civil Aviation: State of the Art (International)

Inmarsat + OnAir

www.inmarsat.com/news/onair-connectivity-line-fitted-qatars-a350-fleet/

January 8, 2015

"Inmarsat distribution partner **OnAir's full inflight connectivity suite is being installed as line fit on Qatar Airways**' brand new Airbus A350 fleet.

Passengers can now choose between mobile phone connectivity and Wi-Fi using Mobile OnAir or Internet OnAir, powered by **Inmarsat SwiftBroadband**.

[…]

OnAir's next generation inflight connectivity services, using Inmarsat GX Aviation, will be launched on the A350 in **2016**.

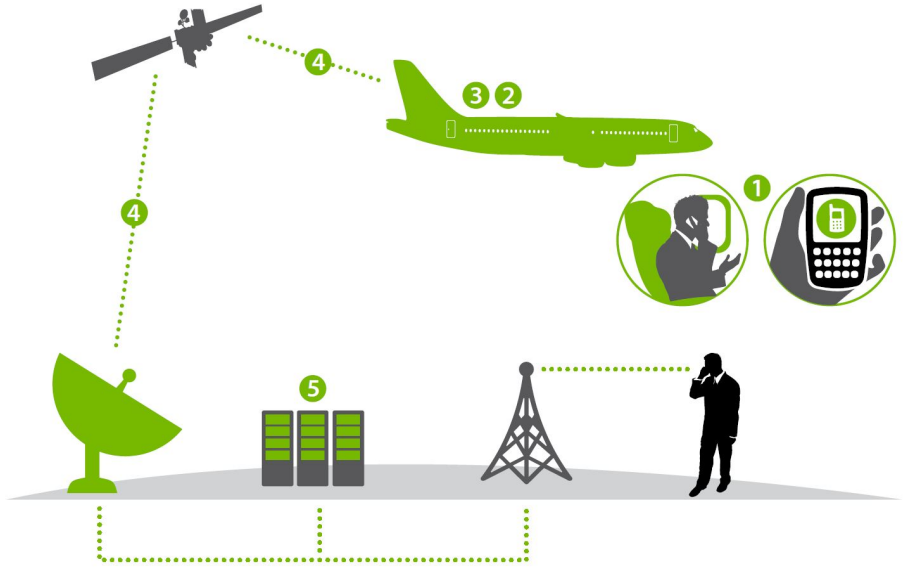
Inmarsat's ground-breaking global **Ka-band network will provide up to 50Mbs to the aircraft –** and deliver a consistent service across the globe."

Advanced Tracking & Communication: Civil Aviation: State of the Art (International)

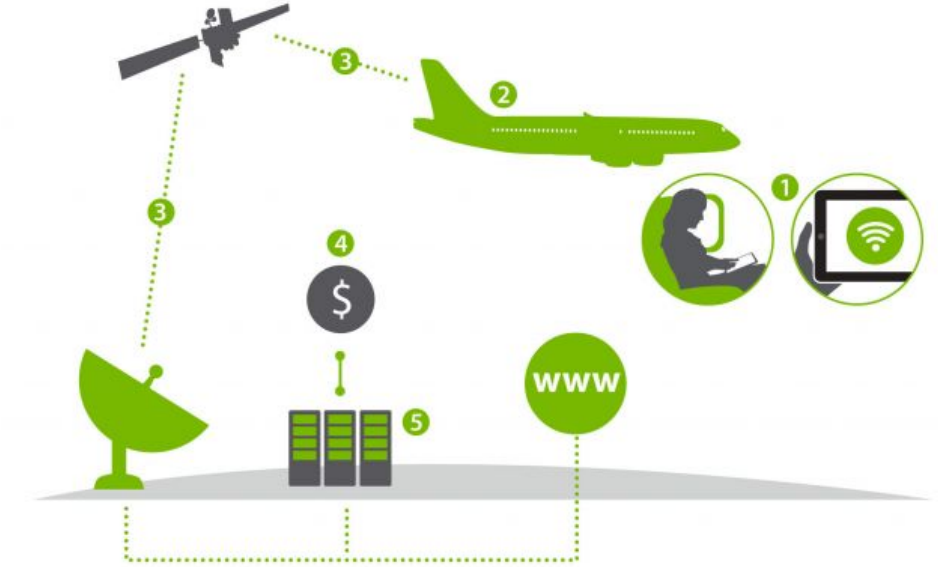
OnAir (Airbus & SITA)
www.onair.aero/en/commercial-airlines-products

Several InFlight secured services including air-ground connectivity for:

- Mobile phones
- **Internet (up to 50Mbs)**
- Link OnAir (various applications…)



onair.aero/en/commercial-airlines-how-it-works-mobile-onair



onair.aero/en/commercial-airlines-how-it-works-internet-onair

State of the Art: Synthesis

- **Improved Satellite Communications**
- **Improved Air-Ground streaming (up to 50Mbs)**
  - **TEXT & NUMERIC messages**
  - **VOICE**

- **Black Box streaming to ground**
  - Flight Parameters
  - Vocal Communications in the cockpit

- **'Virtual Window' into aircraft**

⇒ Who is supposed to process all this data & information?

  - **Big Data…**
  - **Information overload…**

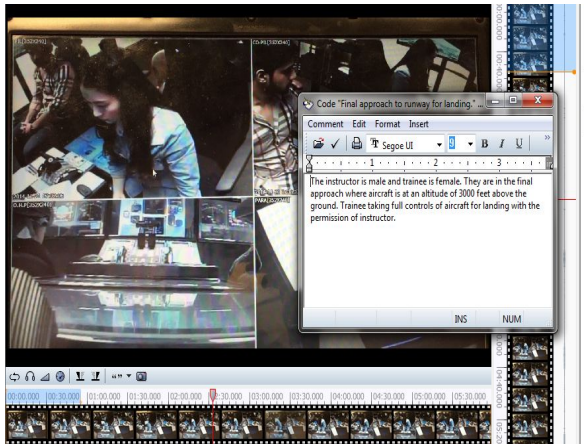
  - **Infrastructure similar to SARSAT?**

Possible Futures…

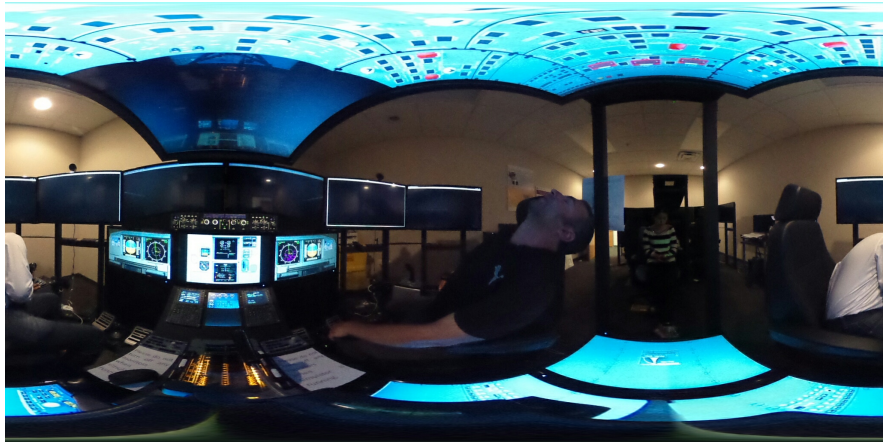
Possible features
accident investigations, training, flight tests, *operations*...

- **Single Pilot…**
- **UAV…**

⇒ **Streaming & Remote Immersion**
- Pictures 360 & 3D
- Videos 360 & 3D
  - **1 stream instead of n**



Adloori, 2015: Cockpit Simulator: Voice & Video analysis for training purposes performed with ATLAS.ti



Stephane, 2015: Cockpit Simulator: **Experimental 360 Picture for Shared Immersive Risk/Situation Awareness** (planar & spherical views).
Samsung Gear VR/Oculus Mobile VR Headset used for **remote visual immersion**.

Possible Futures…

Possible features

similar to current military solutions/UAV already using large bandwidth

- **Single Pilot…**
- **UAV…**

⇒ **Remote Control of Aircraft**

- **In unusual/emergency situations?**
- Other…

Emerging

- **Issues**
  - **Acceptability in communities of practice…**
  - **Security – hacking, take over A/C…**
  - **Viruses**
  - **Infrastructure availability…**

- **Benefits**
  - **Distributed features & responsibilities…**
  - **Crowdsourcing (i.e. passengers,…)**

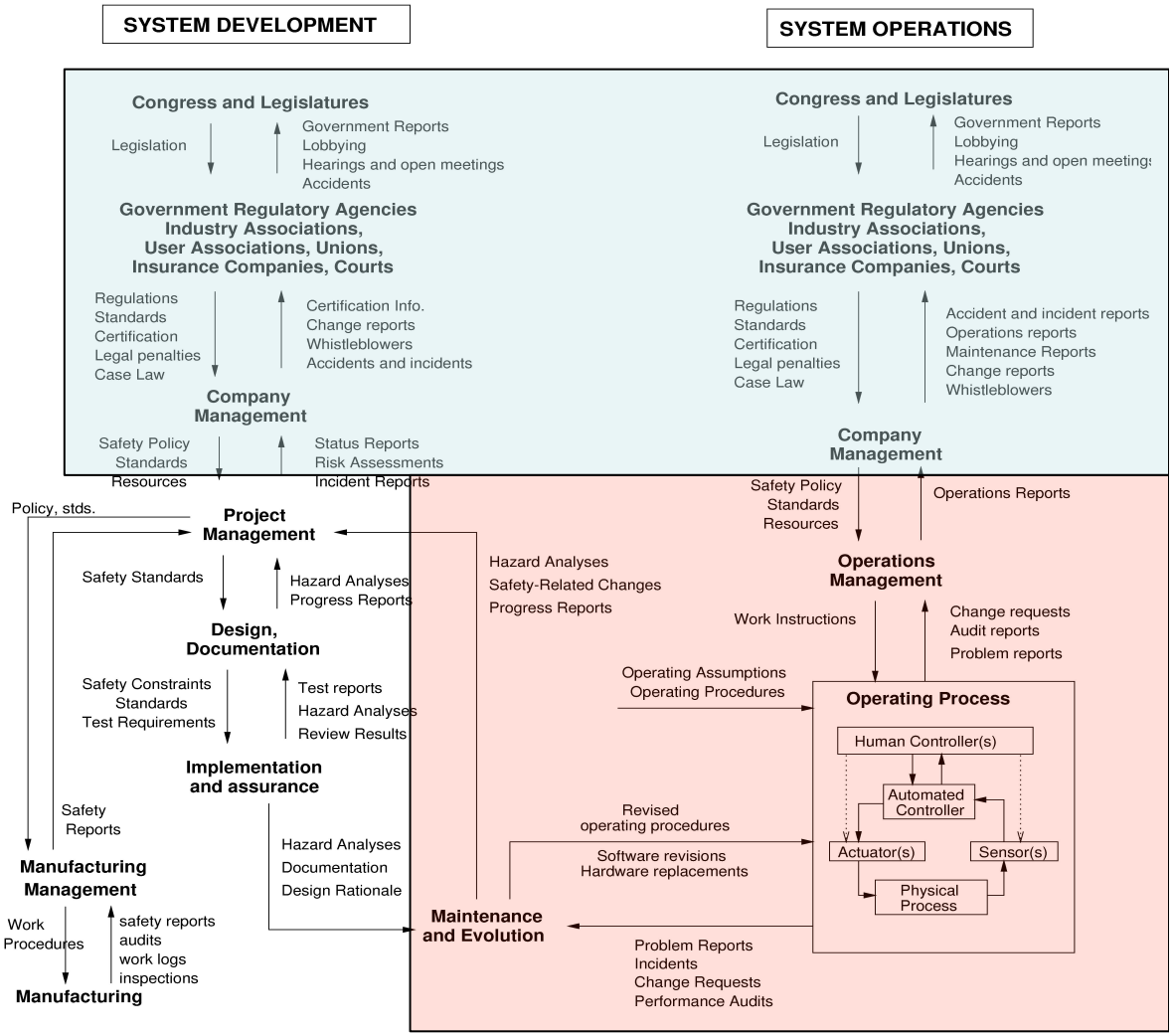
Perspectives: STAMP & STPA for Safety Governance

Improvements

Organizational
- Globalized harmonization
- Investments in infrastructure

Operational
- Evolutions in technology
- Evolutions in practice

- Inter-organization choreography



Leveson, 2004, 2011

!! In Particular !!
- Apply and Use in accident investigation reports

Discussion…

Thanks for your feedback & feedforward

lstephane@fit.edu
www.linkedin.com/in/lucasstephane

References

- Adloori, R. (2015). Cockpit Voice and Video Recorder & Streaming. HCDi Retreat. Melbourne, FL
- Sir Beddington, J. et al. (2011). Blackett Review of High Impact Low Probability Risks. Government Office for Science. Crown Copyright, 2011. UK
- Chen, Charles (2014). World Wide SWIM: Mini Global – A Technical Perspective. SWIM Connect 2014. ATCA's 59 Annual Conference and Exposition, September 27 – October 1, 2014, Fort Washington, MD
- Colledge, G., Ibnyahya, Y. (2014). Inmarsat – Classic Aero and SwiftBroadband ATS Communications Services. CPWG/18 Dec 15-19, ICAO Paris 2014
- FAA (2015). System Wide Information Management (SWIM) Information Access to Transform the Aviation Community. NextGEN, February 2015
- FLYHT Aerospace Solutions Ltd. (2014). http://flyht.com/investors/videos/
- Leveson, N.G. Engineering a Safer World: Systems Thinking applied to Safety. MIT Press, 2011
- Ngo, Thien (2014). World Wide SWIM: Mini Global Project. SWIM Connect 2014. ATCA's 59 Annual Conference and Exposition, September 27 – October 1, 2014, Fort Washington, MD