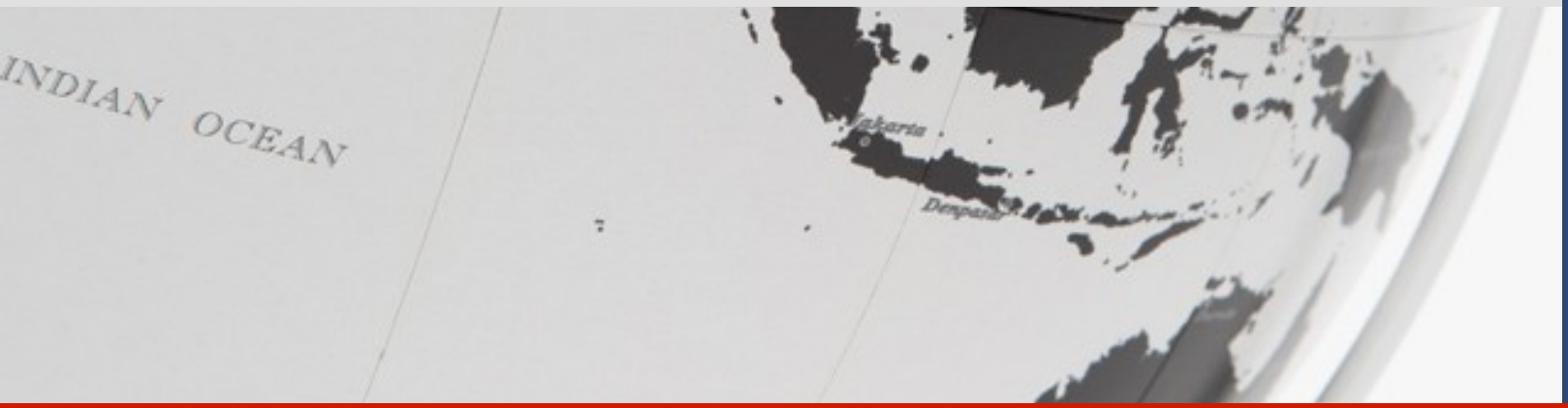
Safety Investigation

Implementing Systems Theory in Accident Investigation using the MIT STAMP based approach Causal Analysis using Systems Theory (CAST)



民 航 意 外 調 查 機 構
AAIA
Air Accident Investigation Authority

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Chief Accident and Safety Investigator
March 2019
Boston/MIT

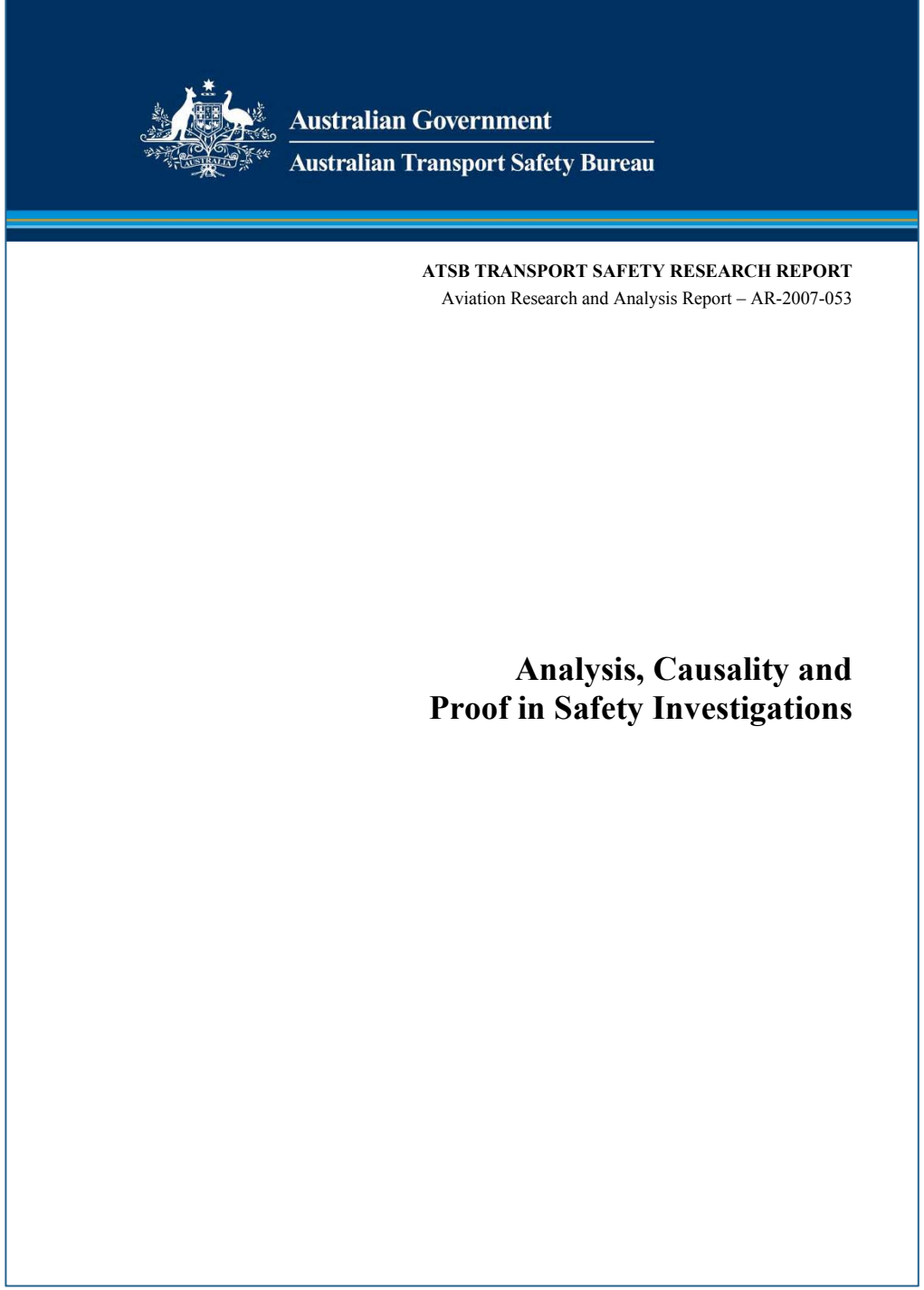
Air Accident Investigation Authority (AAIA)

Hong Kong SAR Air Accident Investigation Authority (AAIA)

Established September 2018

Chief Inspector appointed by the Chief Executive with a mandate to investigate air accidents and incidents as per ICAO Annex 13 and CAP 448B

AAIA is implementing Systems Theory in Accident Investigation using the MIT STAMP based approach Causal Analysis using SystemsTheory (CAST) as the primary analysis tool for accident/incident investigation.



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Annex 13 to the Convention on International Civil Aviation.2 Annex 13 defines an investigation (Chapter 1) as:

A process conducted for the purpose of accident prevention which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes and, when appropriate, the making of safety recommendations.

Understanding Accident Analysis

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Publication title

Analysis, Causality and Proof in Safety Investigations

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Reference No.

Mar2008/Infrastructure 8060

Abstract

The quality of a safety investigation's analysis activities plays a critical role in determining whether the investigation is successful in enhancing safety. However, safety investigations require analysis of complex sets of data and situations where the available data can be vague, incomplete and misleading. Despite its importance, complexity, and reliance on investigators' judgements, analysis has been a neglected area in terms of standards, guidance and training of investigators in most organisations that conduct safety investigations.

To address this situation, the Australian Transport Safety Bureau (ATSB) developed a comprehensive investigation analysis framework. The present report provides an overview of the ATSB investigation analysis framework and concepts such as the determination of contribution and standard of proof. The report concludes by examining the nature of concerns that have been raised regarding the ATSB analysis framework and the ATSB's consideration of these concerns.

The ATSB believes that its investigation analysis framework is well suited to its role as an independent, no-blame safety investigation body. It is hoped and expected that ongoing development and provision of information about the framework can help the safety investigation field as a whole consider some important issues and help develop the best means of conducting safety investigations to enhance future safety.

Uncertainty, probability and likelihood

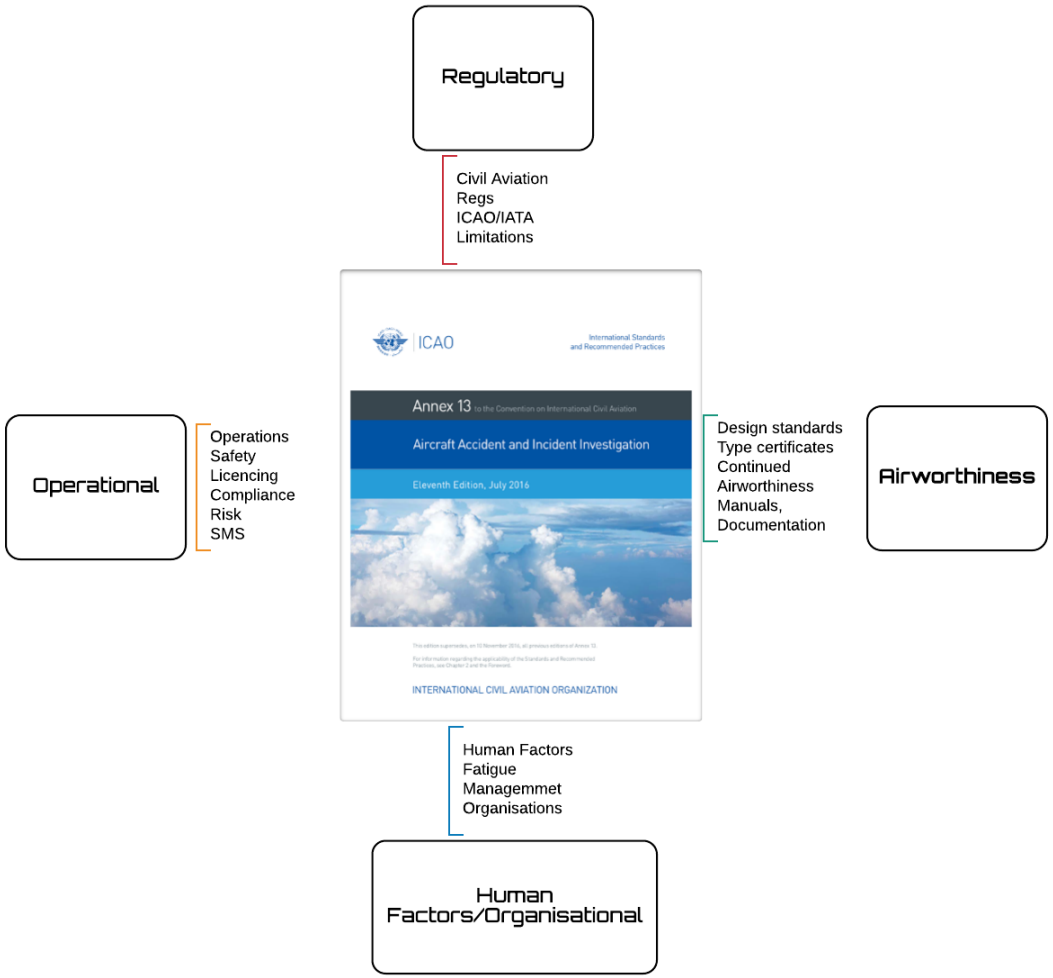
Probability and likelihood Uncertainty is a key component of inductive arguments and reasoning in many fields, and it can be characterised in several ways. In the ATSB analysis guidelines, uncertainty is primarily discussed as the degree of probability that a particular statement is true, based on the available evidence

Arguments, premises and findings

A safety investigation produces a series of findings or conclusions. To develop these findings, the investigation team needs to produce arguments. Arguments consist of a set of statements, one of which is the finding and the rest are premises.

Premises provide the reasons, grounds or justification for believing the finding, whereas the finding is the result of the argument. The premises may consist of items of evidence, as well as assumptions. Findings can also be termed 'claims' or 'hypotheses', although such terms are more useful when discussing proposed findings rather than verified findings.

ICAO Annex Frames of Reference



1. Factual

All information relevant to an understanding of the factual information, analysis and conclusions is included under each appropriate heading;

2. Analysis

Analyse, as appropriate, only the information documented in 1. — Factual information and which is relevant to the determination of conclusions and causes and/or contributing factors.

3. Conclusions

List the findings, causes and/or contributing factors established in the investigation. The list of causes and/or contributing factors should include both the immediate and the deeper systemic causes and/or contributing factors.

4. Safety Recommendations

As appropriate, briefly state any recommendations made for the purpose of accident prevention and identify safety actions already implemented

Inclusion Criteria for Factual Information, Findings and Safety Recommendations

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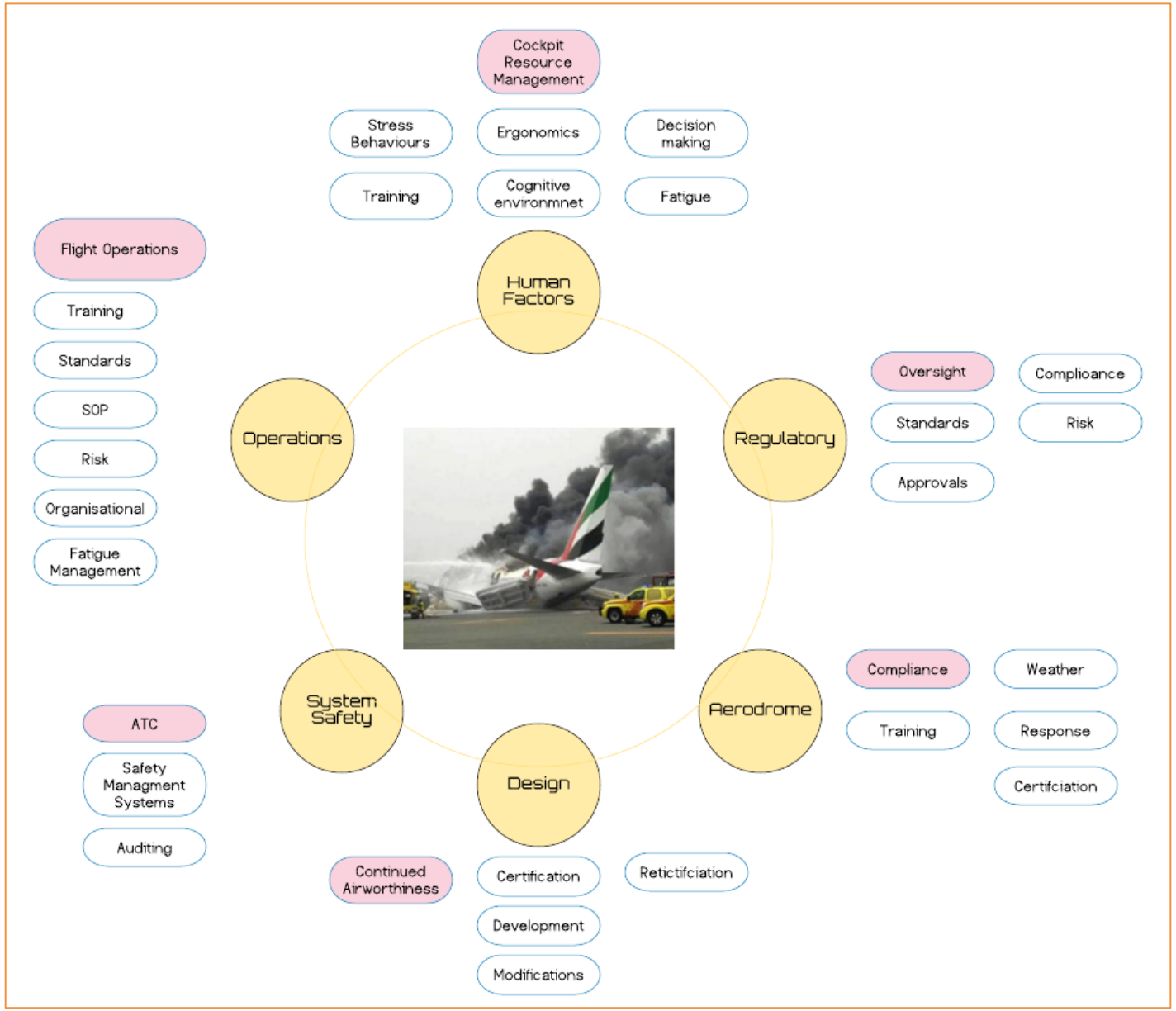
Investigation Scope



Aircraft Condition at Take Off

At the aircraft departure the following conditions apply:

o. Aircraft is airworthy.
o. MEL [faults] and deferred items are cleared [Airworthiness]
o. Crew are within flight duty limitations [Fatigue]
o. Cargo is fully compliant with the international Dangerous Goods regulations [Risk]
o. No security items are logged at Dubai [Access to aircraft]

Time (UTC)	14:53	15:42	Duration (minutes)
Phase	Take off	UCFIT	49

Establishing the Investigation Structure

The problem of 'Root Cause"

1) According to the International Civil Aviation Organisation (ICAO) ADREP classification, this is categorised as **a loss of control accident (LOC-I**)

2) Following a linear direct causal analysis, this is a **Loss of control due to damage to the flight control mechanisms**

3) If you look for a direct root cause it's the initiating action**: 'spontaneous combustion of hazardous materials, resulting in an unconfined class D metal fire, rapidly escalating into an uncontrolled on-board fire'**

4) If you look at cause and effect at a physical level it's **the failure of the separation barrier, the thin (2mm) *polyglass* cargo liner, under extreme thermal loading resulting in the material's failure to maintain its integrity.**

5) If you look at it organizationally, it's **a failure to recognise a documented and specific operational risk where the outcome is always catastrophic.**

6) If looked at from an regulatory and oversight perspective it is **a lack of oversight and a Safety Management System (SMS) which is not responding to operational risk analysis**

7) From a Pilot's or crew perspective this is problem centered around decision making, **it's a deviation or non-compliance with Standard Operating Procedures (SOP's) problem related to the QRH/Non-Normal checklist and operational non-conformance**

8) For the OEM, **it's a design flaw involving a Single point of Failure.**

Duration of the Investigation: Sept 2010 – May 2013: 36 months

Safety Recommendations: Thirty Six [36]

Eight safety recommendations were excluded based on the inclusion criteria:

- ATC/ANS procedures
- Operator's risk analysis
- SMS processes
- IATA dangerous goods standards
- Specific design requirements for cargo aircraft.

Checklists

Crew Alerting

Full Face Oxygen Mask

SFF Training

Evidence Based Training

SR's focused on Technical/Design/Regulatory/Standards Approvals/Cargo/Operations/Ignition sources for lithium battery fires

Safety Recommendations

ICAO

ICAO Technical Instructions

GCAA

Single Points of Failure

Active Fire Detection

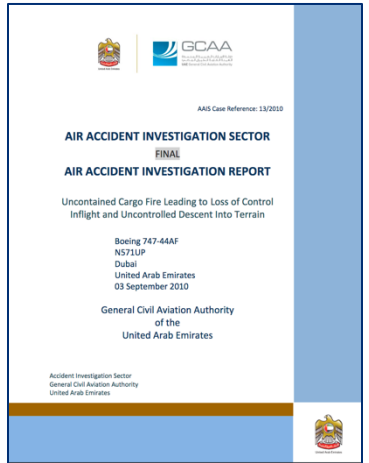
Fire Standards

Certification

Critical Systems Protection

Descent Fire Guidance

ULD Design


GCAA

AAIS Case Reference: 13/2010

AIR ACCIDENT INVESTIGATION SECTOR

FINAL

AIR ACCIDENT INVESTIGATION REPORT

Uncontained Cargo Fire Leading to Loss of Control Inflight and Uncontrolled Descent Into Terrain

Boeing 747-44AF
N571UP
Dubai
United Arab Emirates
03 September 2010

General Civil Aviation Authority
of the
United Arab Emirates

Accident Investigation Sector
General Civil Aviation Authority
United Arab Emirates

CAST REVIEWED SAFETY RECOMMENDATIONS

Safety Recommendations: Forty Six [46]

NVG/IR Cameras

Training Options

Checklists

Crew Alerting

Full Face Oxygen Mask

SFF Training

Evidence Based Training

Safety Recommendations

ICAO

ICAO Technical Instructions

GCAA

Operator Risk

SMS

Single Points of Failure

Active Fire Detection

Fire Standards

Certification

ATC

RISK

RISK

Critical Systems Protection

Descent Fire Guidance

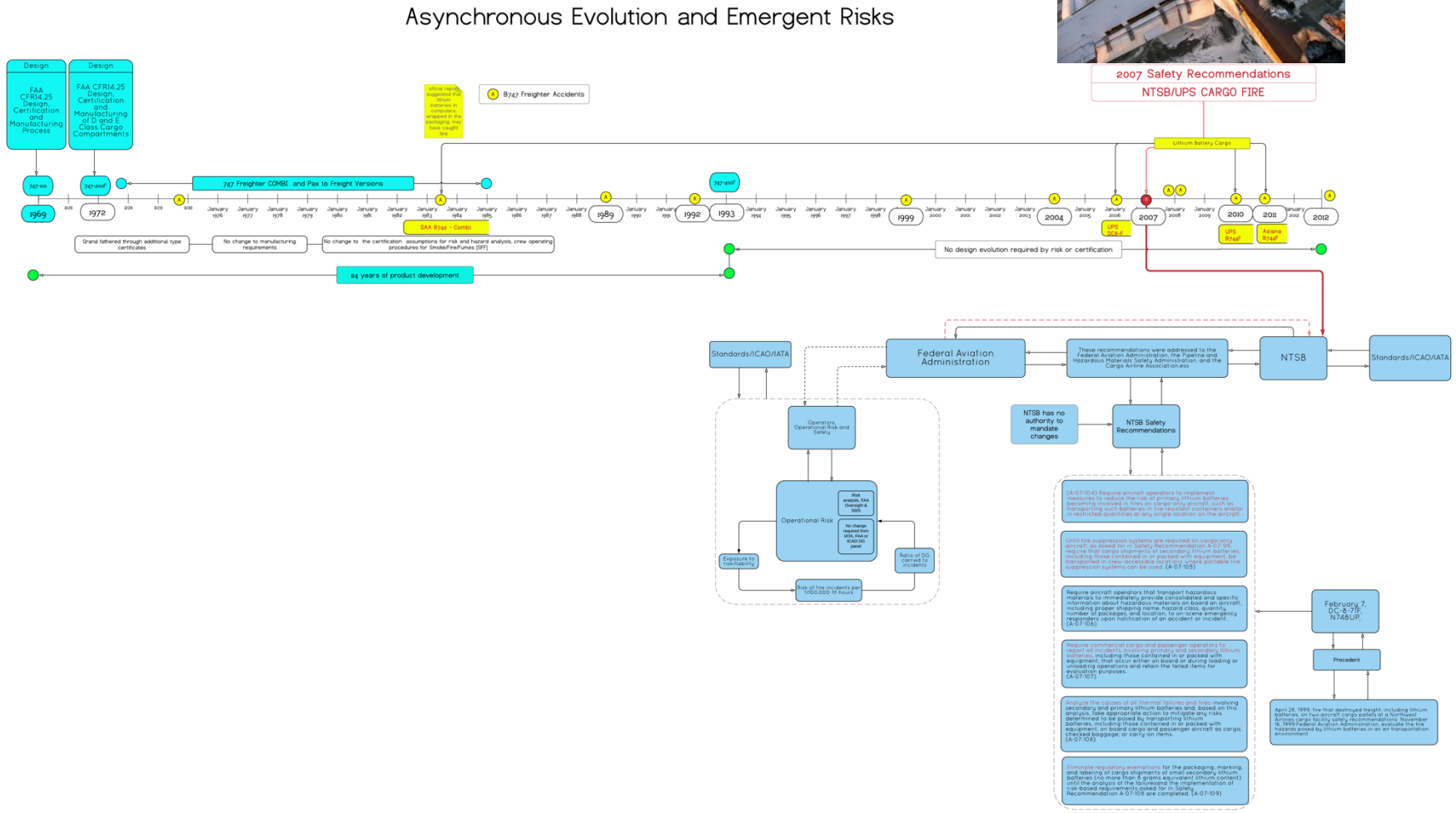
ATC

Packaging

ULD Design

Screening

Asynchronous Evolution and Emergent Risks



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Amsterdam University of Applied Sciences

University of Bolton
Teaching Intensive, Research Informed

TRACING NEW SAFETY THINKING PRACTICES IN SAFETY INVESTIGATION REPORTS

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3rd International Cross-industry Safety Conference (ICSC)
Amsterdam, 31 October – 2 November 2018

CREATING TOMORROW

Analysis Tools – Model Groups

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SAFETY/ACCIDENT MODEL GROUPS

Type	Brief description	Example model(s)	Code
Sequential	Direct cause-effect relationships: clearly defined timeline of failures, errors and violations that lead to an event.	Domino	SEQ
Epidemiological	Direct and indirect cause-effect relationships: clearly defined timeline of active failures along with long-lasting effects of latent problems that contribute to active failures.	Swiss cheese	EPD
Systemic	Dynamic, emerging and complex system behaviours: examining interactions, interdependencies and relationships between parts to understand a system as a whole, including effects of the behaviour of individual elements.	STAMP AcciMap	SYS

Using System Theory to Understand Accident Causality

Systems Theory considers accidents as arising from the interactions among systems components and usually does not specify single causal variables or factors.

Traditional safety models and event chain models focus on unsafe acts or conditions

System safety models examine what went wrong with the systems operations or organisation to allow the event to occur

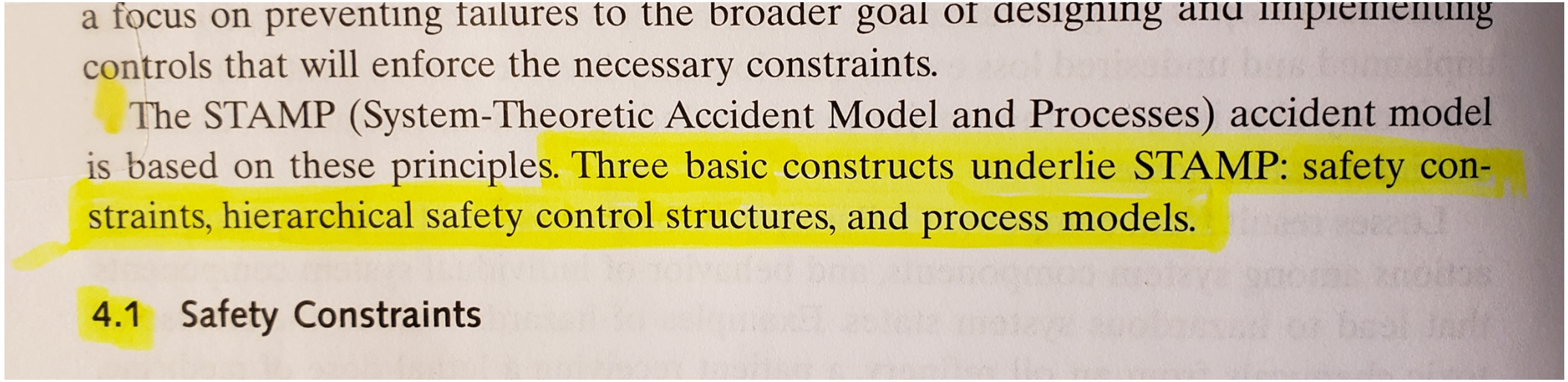
Systems approach treats safety and an emergency property, the product of complex interactions of components of the systems.

Emergent properties – e.g. safety – are controlled or enforced by constraints (control laws) related to the behaviour of the system components

Safety = Control Problem

Safety Constraints

Three Basic Constructs Underlie STAMP



a focus on preventing failures to the broader goal of designing and implementing controls that will enforce the necessary constraints.

The STAMP (System-Theoretic Accident Model and Processes) accident model is based on these principles. Three basic constructs underlie STAMP: safety constraints, hierarchical safety control structures, and process models.

4.1 Safety Constraints

- Safety Constraints
- Hierarchical Control Structures
- Process Models

Basic Constructs: STAMP

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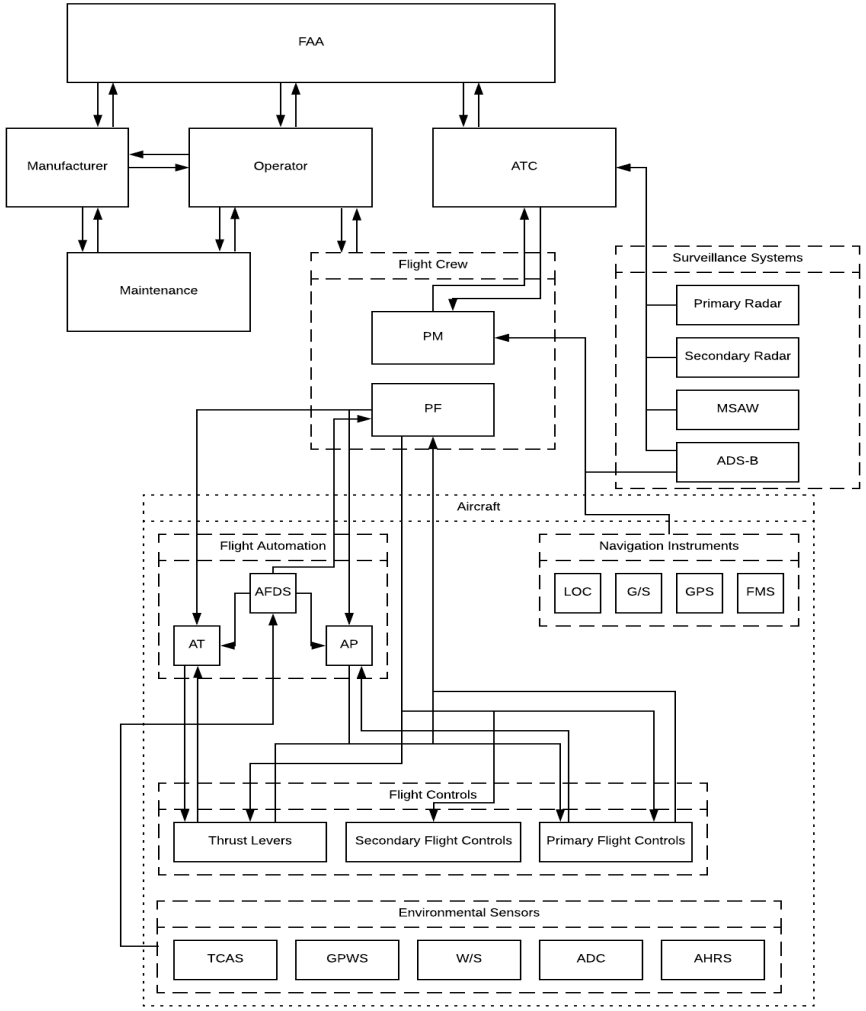
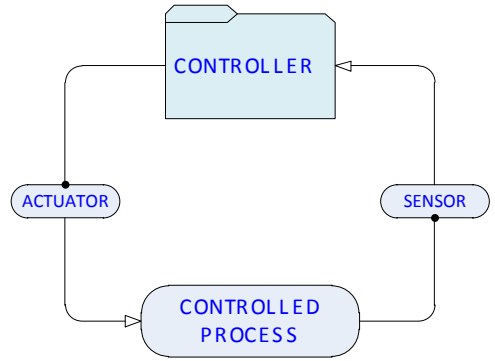
Hierarchical Control Structures



Safety Constraints

In **STAMP**, accidents are conceived as resulting not from component failures, but from inadequate control or enforcement of **safety**-related **constraints** on the development, design, and operation of the system. The most basic concept in **STAMP** is not an event, but a **constraint**



System Control Loop

Process Models

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CAST Process

1. Identify the System Level Hazards involved in the loss
2. Identify the Control Structure designed to control the Hazard
3. Determine the Proximate Events leading to the loss
4. Analyze the loss at the Physical System Level
   - Identify the physical controls and equipment involved
   - Identify any physical safety requirements and constraints meant to prevent this accident
   - Identify any failures or inadequate controls in the physical equipment
   - Identify contextual factors that explain the physical failures or inadequate controls
5. Analyze higher levels of control to determine how and why each successive higher level contributed to inadequate control at the current level
   - Identify the unsafe decisions and control actions
   - Identify process model flaws (beliefs) that explain the unsafe decisions and control actions
   - . Identify contextual factors that explain why the behaviour seemed appropriate at the time
   - Identify the safety-related responsibilities for the next higher level of control
6. Look at factors that involve the interaction among system components and not just individual components.
   - Identify communication and coordination deficiencies that contributed to the events.
   - Identify dynamics and changes over time that led to the behaviors and events.
   - Identify safety culture flaws contributing to the events.

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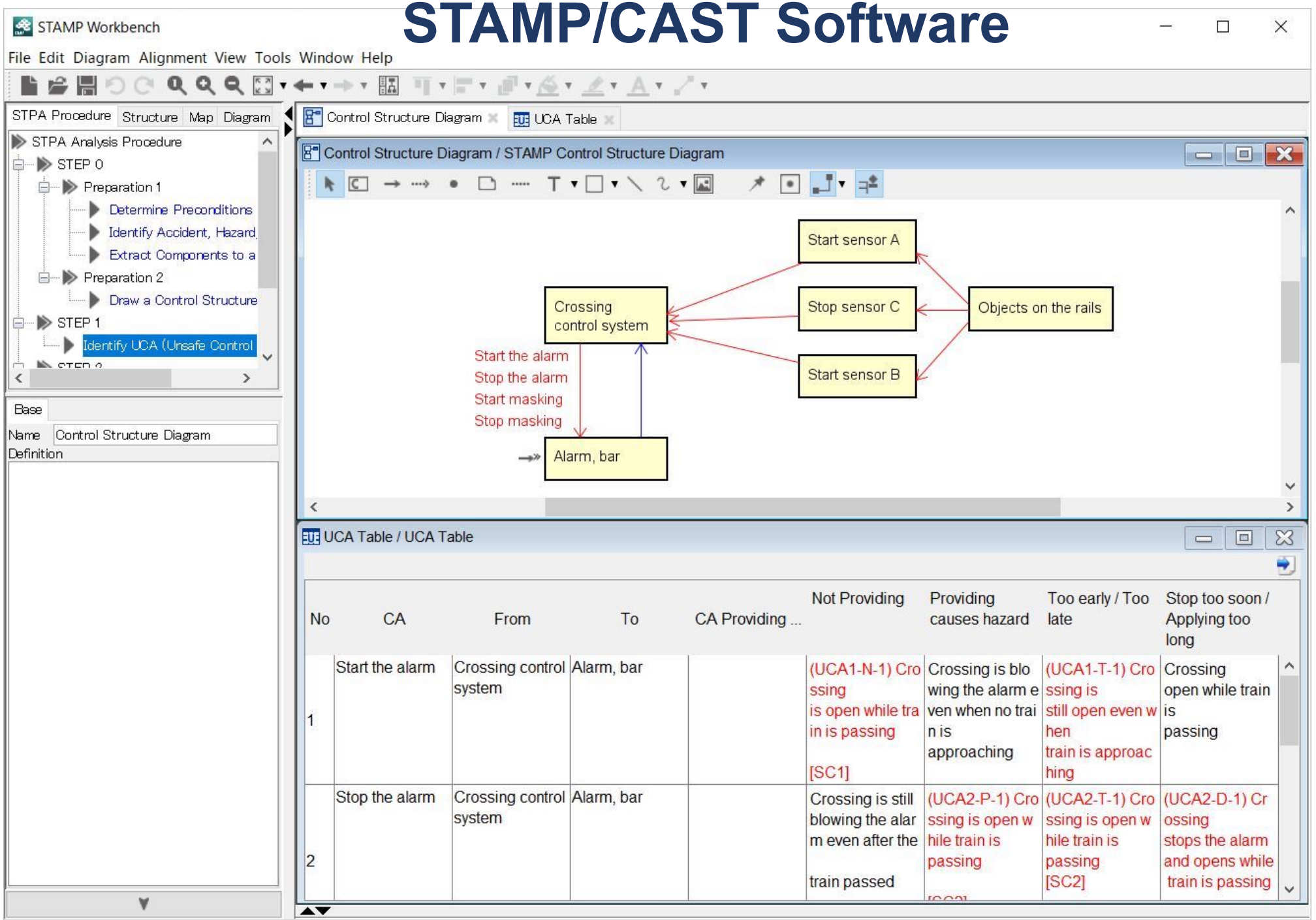
STAMP/CAST Software



No	CA	From	To	CA Providing ...	Not Providing	Providing causes hazard	Too early / Too late	Stop too soon / Applying too long
1	Start the alarm	Crossing control system	Alarm, bar		(UCA1-N-1) Crossing is open while train is passing [SC1]	Crossing is blowing the alarm even when no train is approaching	(UCA1-T-1) Crossing is still open even when train is approaching	Crossing open while train is passing
2	Stop the alarm	Crossing control system	Alarm, bar		Crossing is still blowing the alarm even after the train passed	(UCA2-P-1) Crossing is open while train is passing	(UCA2-T-1) Crossing is open while train is passing [SC2]	(UCA2-D-1) Crossing stops the alarm and opens while train is passing

STAMP/CAST Software

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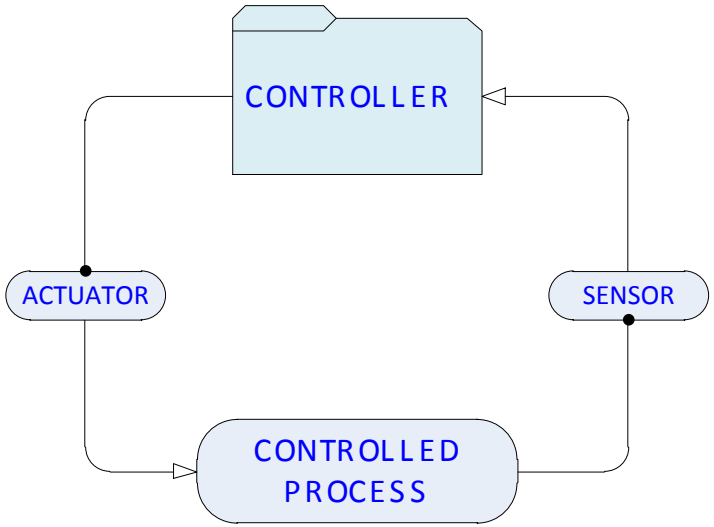
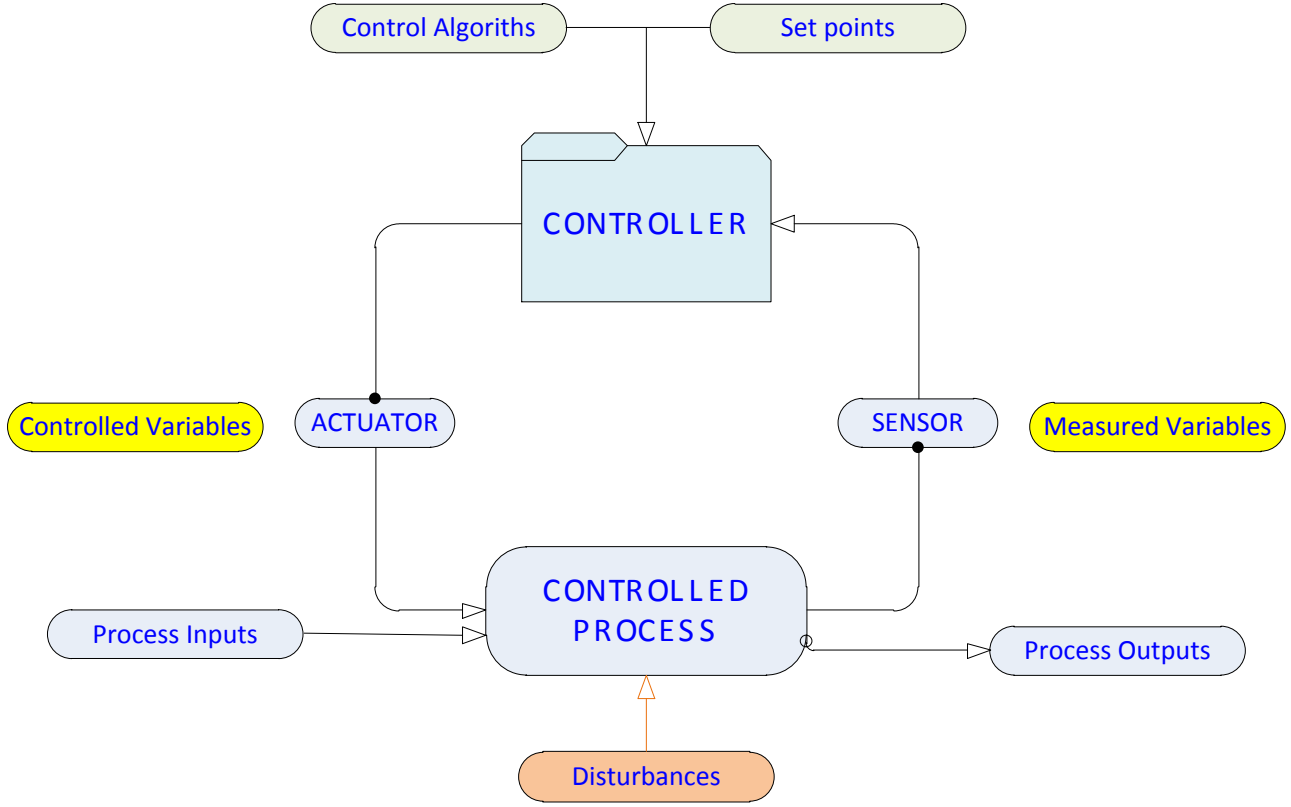
- Enables the investigator to concentrate on investigation analysis
  - As automated as possible.
  - Analysts only need to focus on thinking.
  - CS diagrams from the Component extraction table is automatically generated.
  - Guided chart editing with intuitive operation is available.
- Help analysis. It's not just an editing tool.
  - Automatic ID numbering (proactive support for repetitive analysis)
  - Real-time Model collaboration
  - Highlights of related information, parallel display
- Guide the analysis procedure, but does not limit operational scope
  - Step guidance window for beginner
  - Available from any step for experts
  - It can be used as a construction tool of CS Diagram.
  - Two-way support of Diagram Table, and Table Diagram

CAST Software



System Control Loop



System Control Loop

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