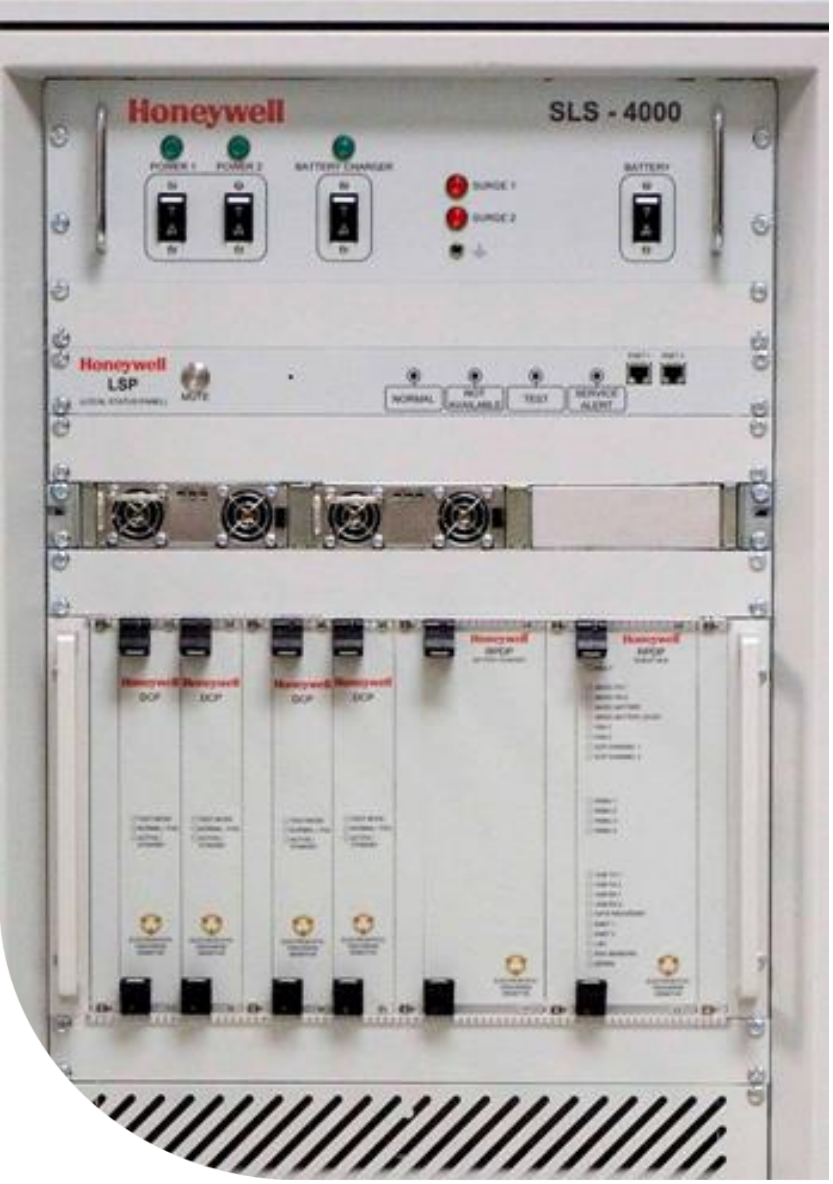

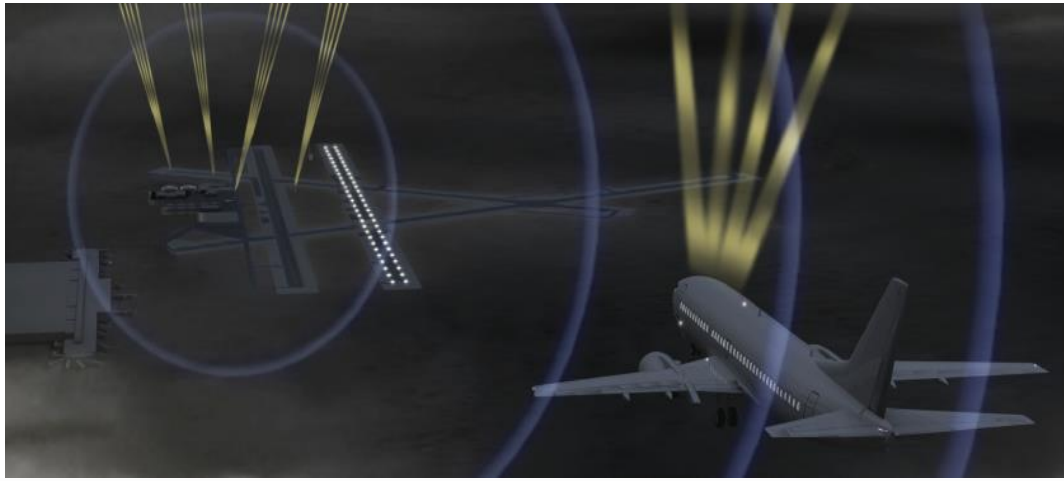

Seoul, Korea
3-5 June 2019

GBAS DESIGN SAFETY ASSURANCE

ICAO GBAS/SBAS Implementation Workshop

Honeywell SmartPath® SLS-4000 complies with the following Requirements and Standards

- ICAO SARPS International Civil Aviation Organization (ICAO) Annex 10, Volume I, Radio Navigation Aids, Sixth Edition (including amendments 1-87), July 2006
- EUROCAE/ED-109 Guidelines for Communication, Navigation, Surveillance, and Air Traffic Management (CNS/ATM) System Software Integrity Assurance, 2002
- ICAO Doc. 8071 Volume II, Manual on Testing of Radio Navigation Aids, Fifth Edition, 2007
- FAA-E-3017 Category I Local Area Augmentation System Ground Facility, Non-Fed Specification, dated 29 September 2009
- FAA-E-AJW44-2937A Category I Local Area Augmentation System Ground Facility, Non-Fed Specification, dated 21 October 2005
- ICD-GPS-200C NAVstar GPS Space Segment/Navigation User Interfaces
- RTCA/DO-178B Software Considerations in Airborne Systems and Equipment Certification
- RTCA/DO-245A Minimum Aviation System Performance Standards for the Local Area Augmentation System (LAAS)
- RTCA/DO-246C GNSS-Based Precision Approach Local Area Augmentation System (LAAS) Signal-in-Space Interface Control Document (ICD)
- RTCA/DO-254 Design Assurance Guidance for Airborne Electronics Hardware
- RTCA/DO-278 Guidelines for Communication, Navigation, Surveillance, and Air Traffic Management (CNS/ATM) System Software Integrity Assurance, 2002
- SAE/ARP-4754 Certification Considerations for Highly Integrated or Complex Aircraft Systems
- SAE/ARP-4761 SAE Aerospace Recommended Practice, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment, December 1996

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FAA GBAS Certification Phases

System Design Approval (SDA) – Manufacturer

- Ground station system design meets requirements
- Developed to appropriate design assurance levels

Facility Approval – Owner/ANSP/Airport

- Ground station installed
  - Safety Case for Installation (extrapolation of SDA safety case)
- Maintenance technicians trained, certified

Service Approval – Operator/Airline

- Aircraft equipped
- Pilot crews trained

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Dual-focus of SDA

- Technical Correctness
  - Integrity of pseudorange correction, broadcast sigma
  - Fault modes, hazard mitigations, monitor perform (Pmd, Pfd)
    - Error source behavior, statistical distribution
  - Requirements correct, traceability, implemented correct
- Process Rigor
  - RTCA/DO-178B/278,-254, SAE/ARP 4754
  - Plan, Process, Summary
    - Approval (System level), Software, Hardware
  - Process compliance, artifact review
  - Configuration control, change management

The Process Assures System Safety

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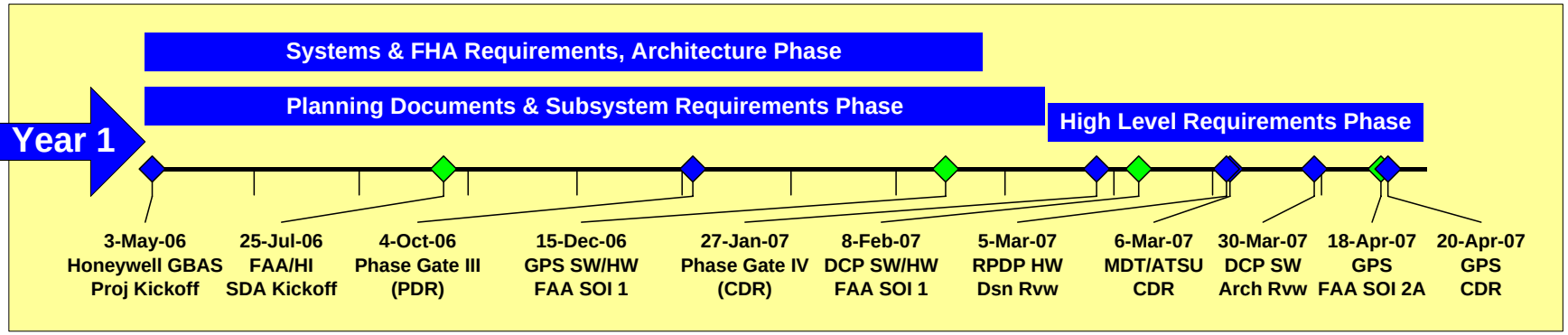
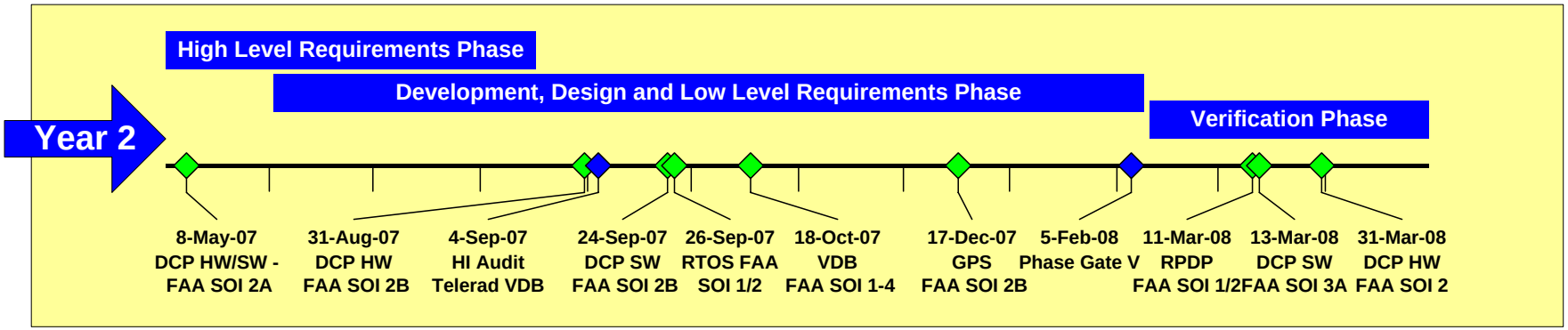
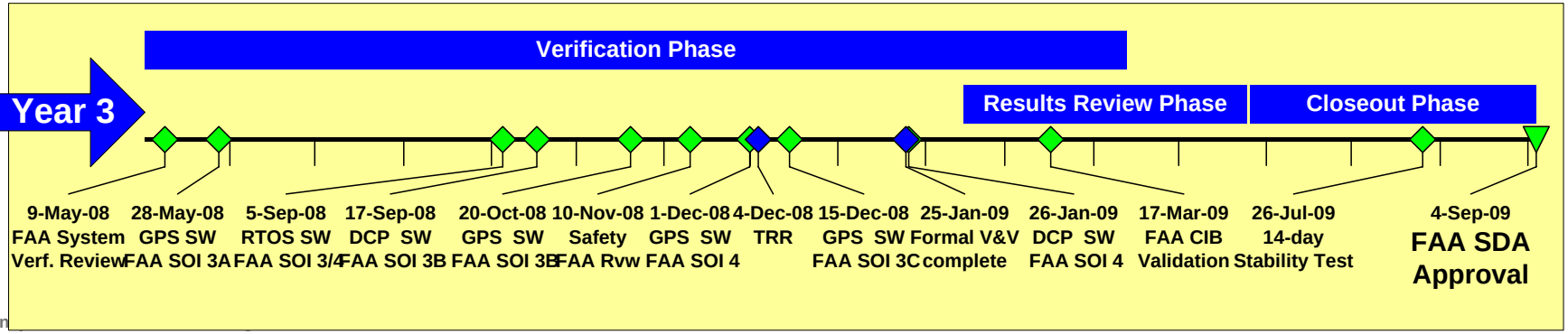
SmartPath™ SDA Development Milestones





FAA Audit Review Honeywell Design Activity



A Thorough Process with Predefined Checkpoints

Safety Assurance Process

- The FAA's SDA Plan [14] recommends the safety process follows guidelines provided in SAE/ARP-4754 [21] and SAE/ARP-4761 [22].
- Honeywell's process relative to SLS-4000 defined in "LGF System Safety Assurance Program Plan" [2]
- Safety process is characterized by systematic evaluations performed at progressively lower levels of system abstraction
  - Functional Hazard Assessment (FHA) – Evaluates system functions
  - Preliminary System Safety Assessment (PSSA) – Evaluates proposed architecture
  - System Safety Assessment (SSA) – Evaluates final design

Safety discipline involved throughout development and verification processes

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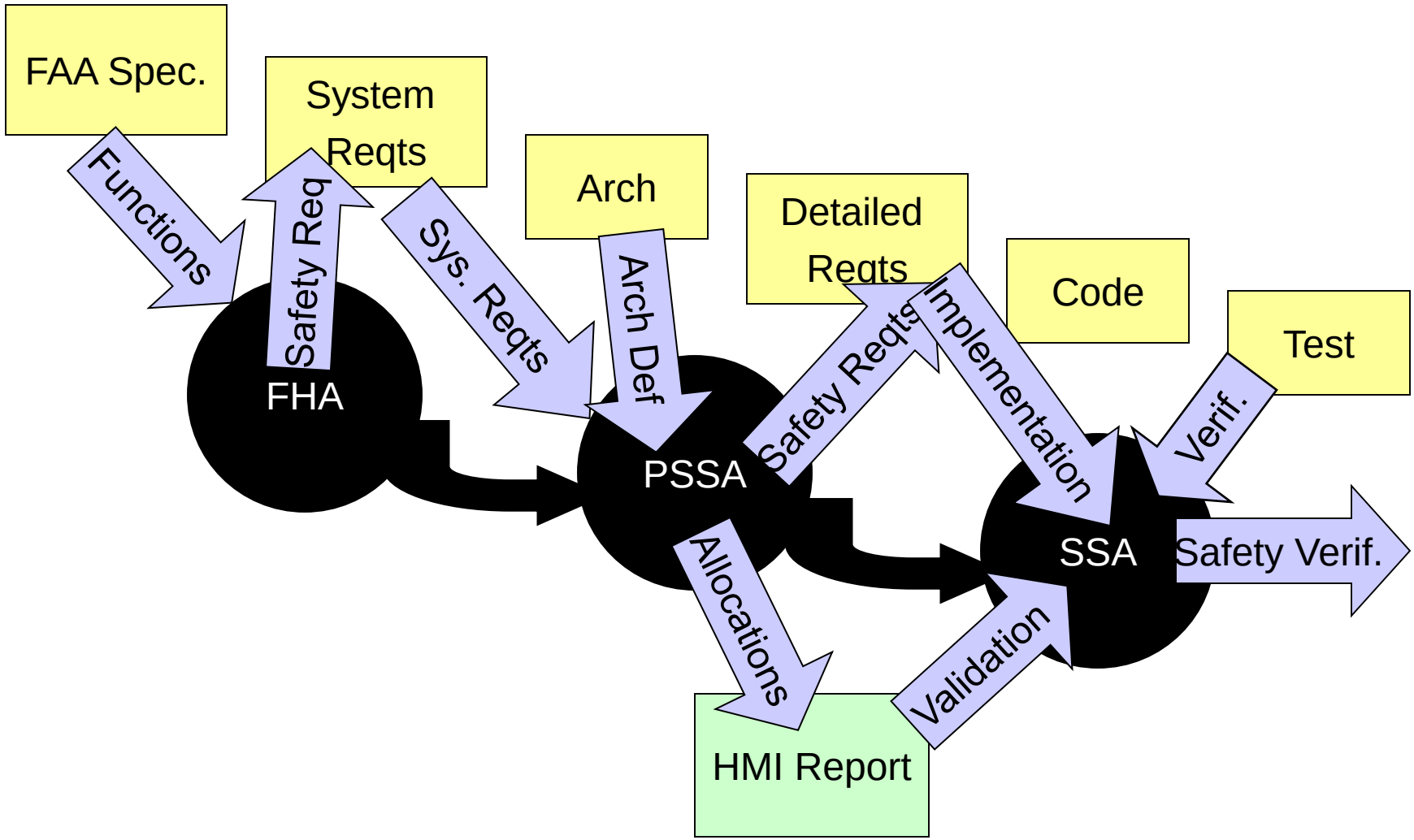
Safety Assurance Process



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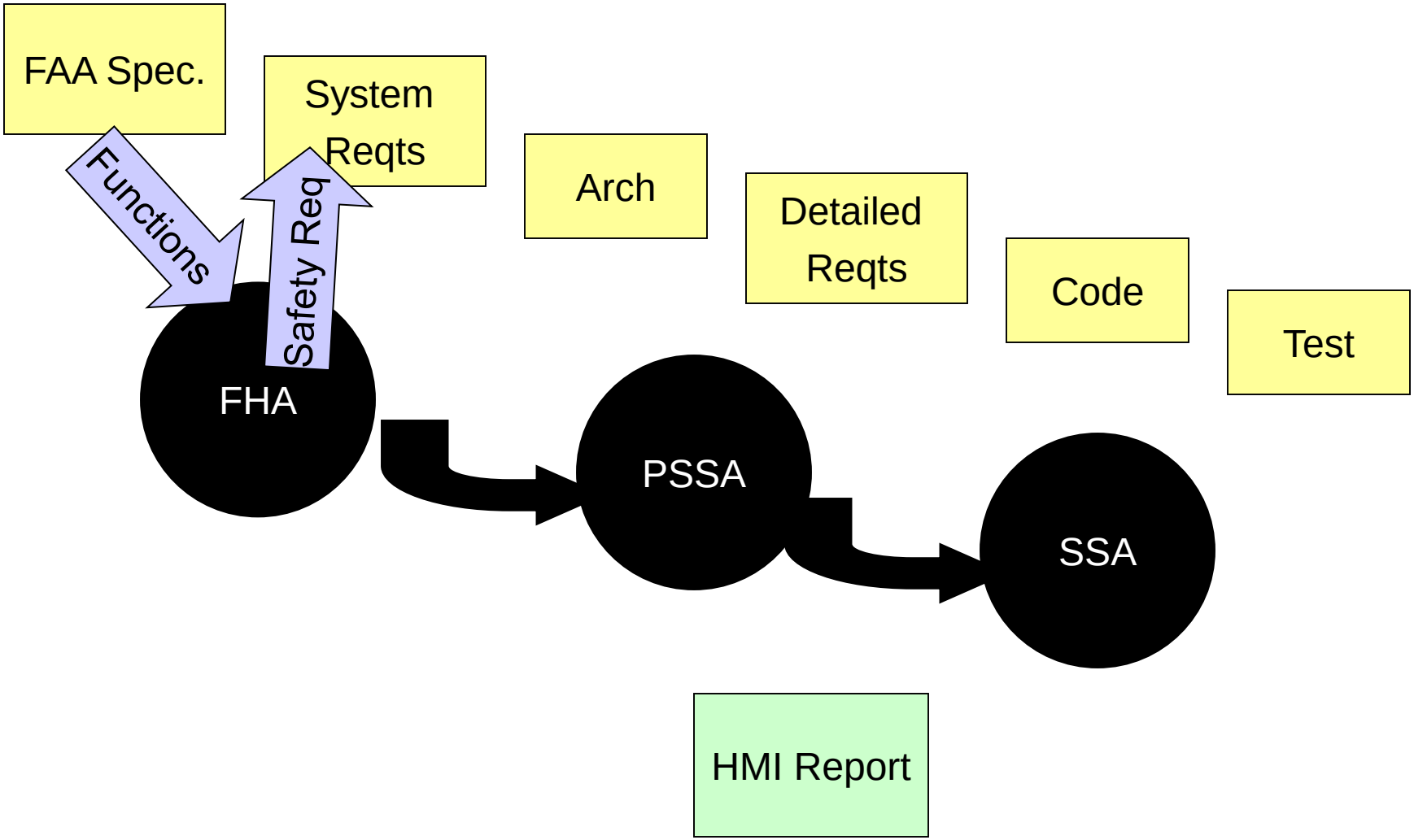
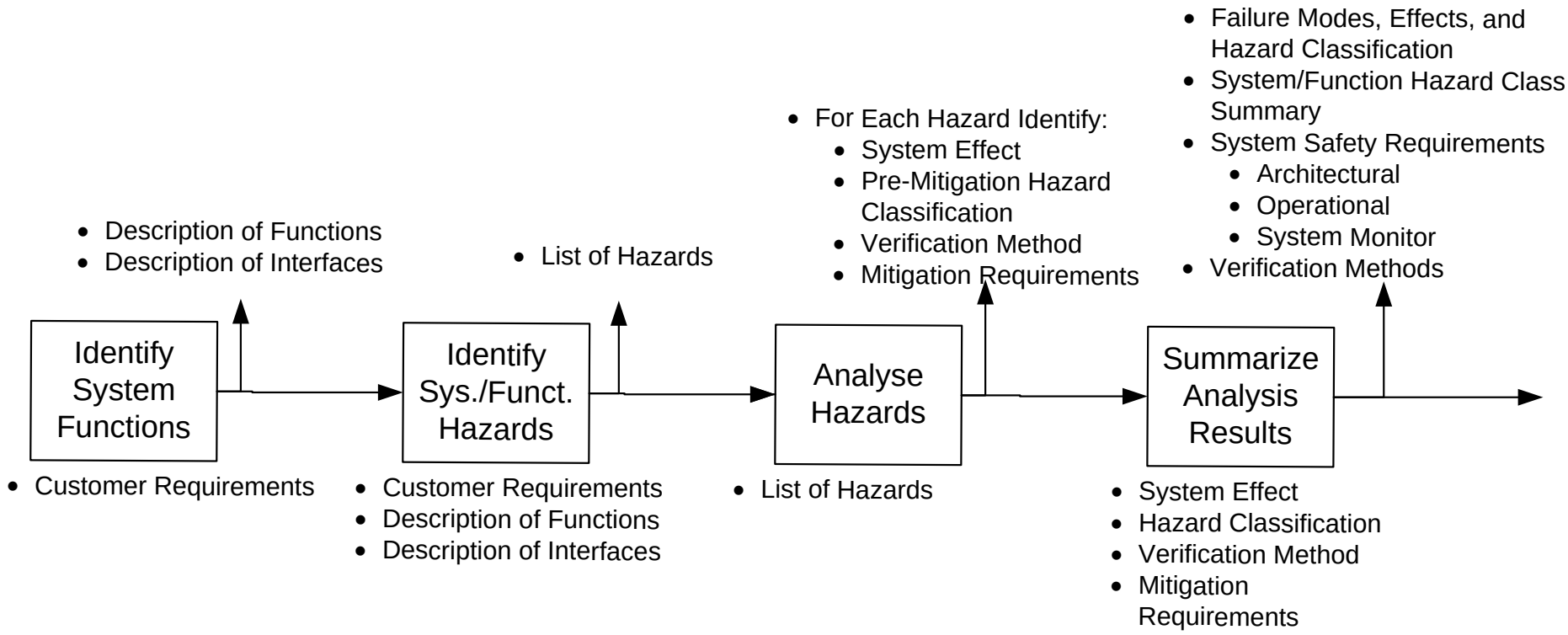
Safety Assurance Process - FHA



As an Example—Later Slides Show Process, not Details

Safety Assurance Process - FHA



For Each Assessment There is a Process Map

Safety Assurance Process - FHA

DATE: _____ SYSTEM FUNCTIONAL HAZARD ASSESSMENT (FHA) PREPAREDBY: _____

SYSTEM: LAAS REVIEWED BY: _____

Function	Failure Condition (Hazard Description)	Effect of Failure Condition on System	Hazard Classification	Reference to Supporting Material	Verification Method

HAZARD CLASSIFICATION

Class I: Catastrophic Class II: SevereMajor Class III: Major

Class IV: Minor Class V: No Effect

Forms to be Completed for Each Assessment

Safety Results - FHA

- Safety Definitions
  - Integrity – The probability of transmitting out-of-tolerance navigation data for 3-seconds or longer in any 150-second interval
  - Continuity – The probability of an unscheduled interruption of the VHF transmission for 3-seconds or longer in any 15 second interval
  - Availability – The proportion of time during which service is provided, computed over a long period (typically a year)

Safety Results - FHA

- Severe-Major Hazard Classification
  - Approach Integrity due to LGF failure, anomalous environmental or atmospheric effects – 1.5×10^{-7} in 150-seconds
  - Approach Integrity under fault free or no more than Reference Receiver fault – 5×10^{-8} in 150-seconds
- Minor Hazard Classification
  - Unscheduled interruption of VDB transmission (Loss of Continuity) – 1.0×10^{-6} in 15-seconds
  - Unscheduled loss of sufficient Reference Receivers or Ranging Sources (Loss of Continuity) – 2.3×10^{-6} in 15-seconds
  - Availability – 0.99

LGF Specification safety requirements validated

Results are Classified by Severity

Safety Results - FHA

- Minor Hazard Classification
  - VDB Operates in a manner that could interfere with nearby LGF system for 1 second – 5.0×10^{-7} in 30-seconds. This encompasses:
    - VDB Power 3 dB above assigned power level (LGF Requirement)
    - VDB transmission outside of TDMA time slots (LGF Requirement)
    - VDB transmission outside of assigned frequency (Derived Requirement)
  - VDB transmission exceeds unwanted or adjacent channel emissions for 1-second – 1.0×10^{-2} in 30-seconds (Derived Requirement)
  - VDB Power 3 dB above assigned power level for 1 second – 2.0×10^{-7} in 30-seconds
  - VDB transmission outside of TDMA time slots for 1-second – 1.0×10^{-7} in 30-seconds

Derived Safety Requirements

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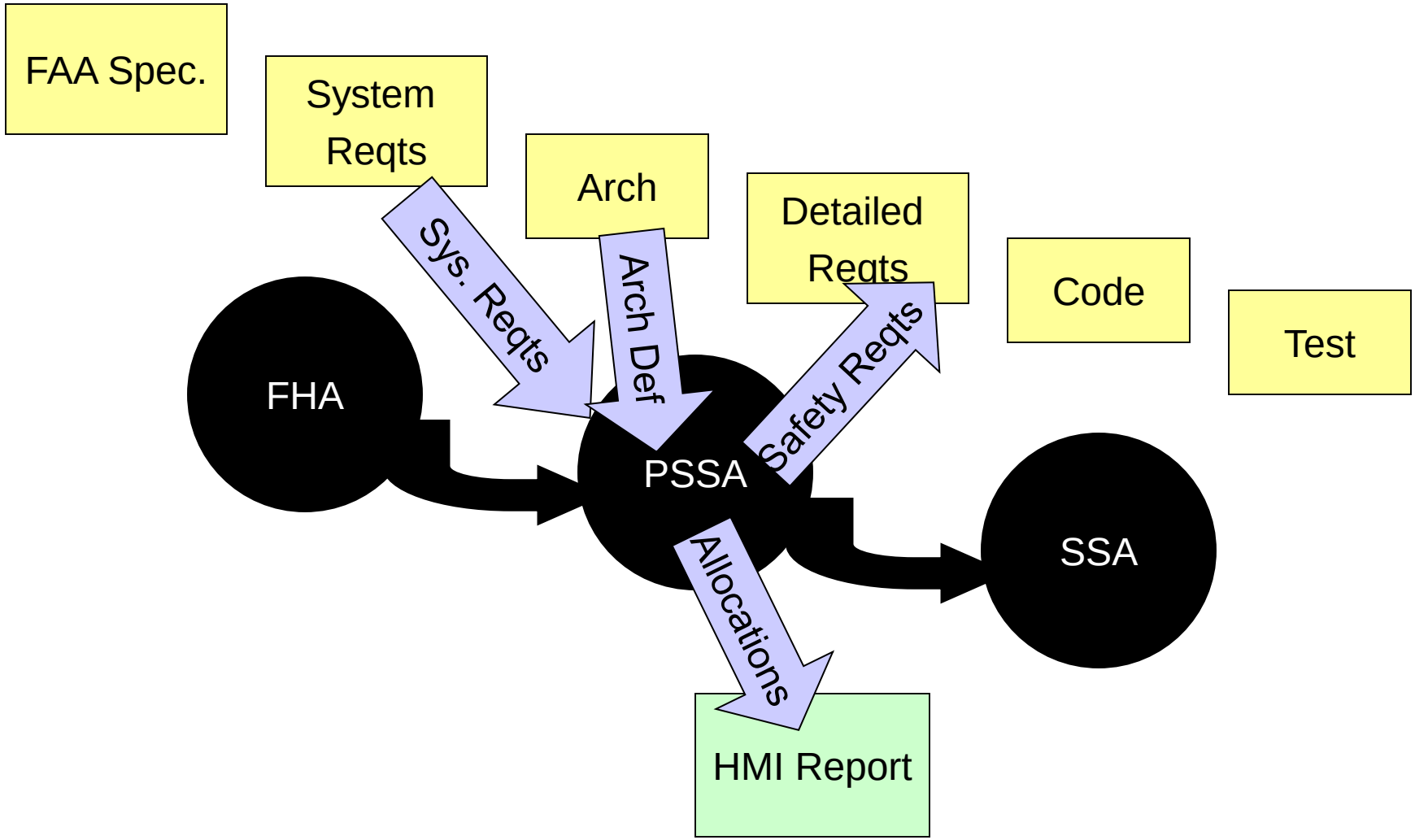
Safety Results - FHA

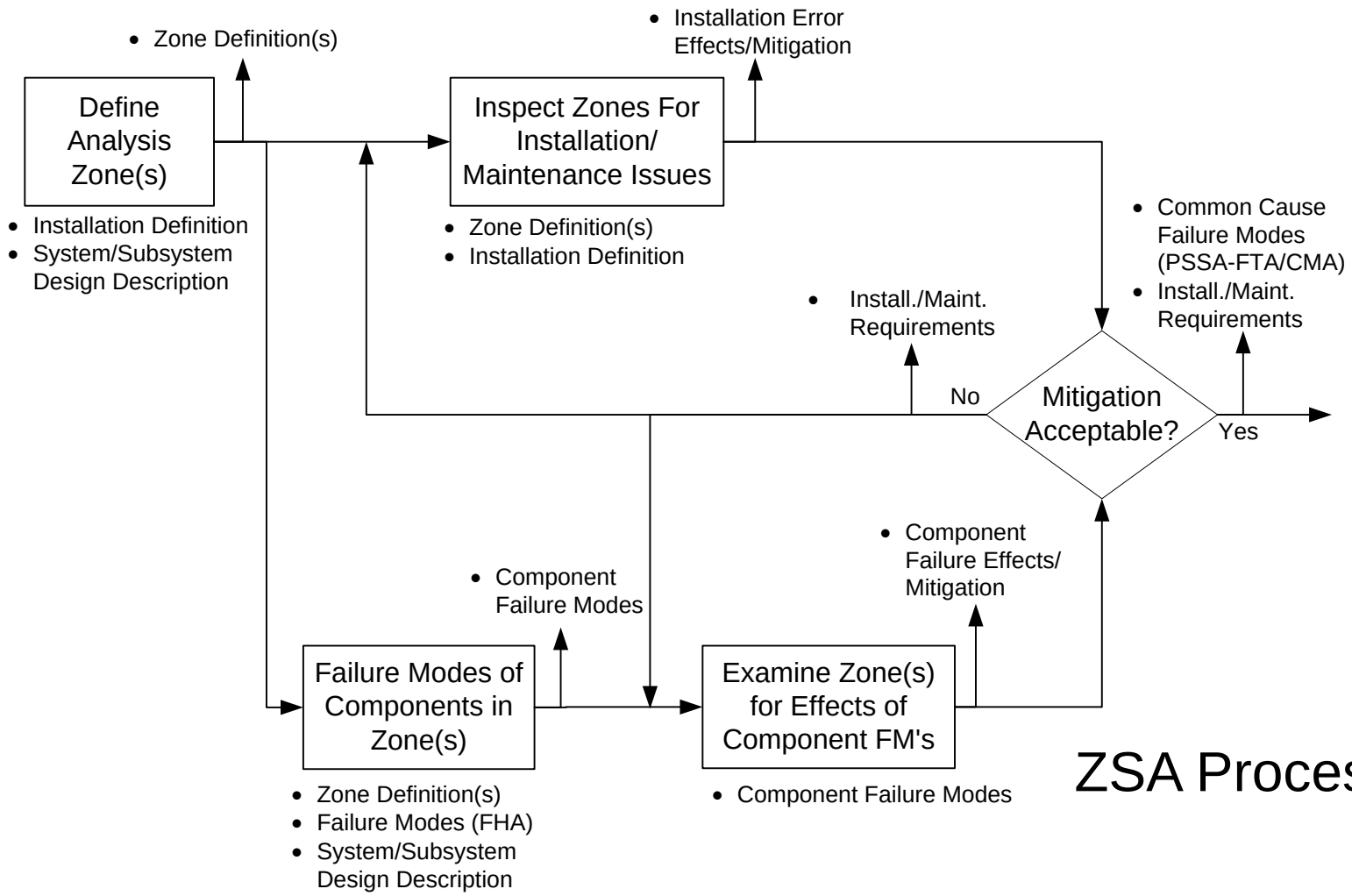
- LGF Hazard Classifications by System Function:
  - Primary/Secondary Power (Severe-Major)
  - LGF Correction Processor/Integrity Monitor (Severe-Major)
  - Reference Receiver (Severe-Major)
  - VDB Transmitter (Minor)
  - VDB Monitor (Minor)
  - VDB Antenna (Severe-Major)
  - LSP (Minor)
  - MDT (Severe-Major)
  - ATSU (Minor)
  - Data Recorder (No Effect)
  - Environmental Sensor (Minor)

Preliminary System Safety Assessment (PSSA)



PSSA/System Requirements→Detailed Requirements

Safety Process – PSSA/ZSA



ZSA Process Map

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Safety Process – PSSA/ZSA

ZSA Form

SYSTEM:			ZONE:	ANALYST:
ID #	Source	Hazard	Effect	Mitigation
1-1				
1-2				
1-3				
1-4				
1-5				
1-6				

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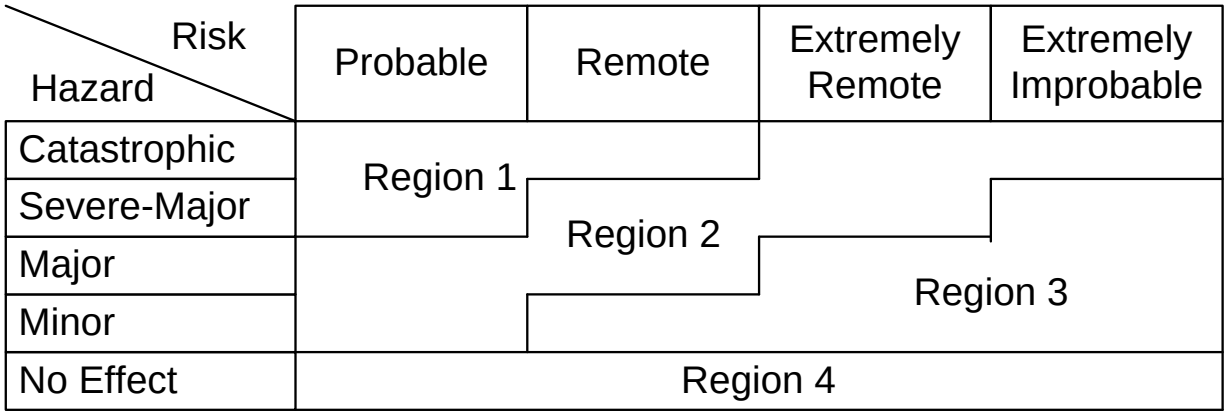
Safety Process – PSSA/PRA

- Analysis
  - Assess pre and post mitigation against hazard/risk index



  - Region 1: Design action required to eliminate or control hazard
  - Region 2: Hazard must be controlled or hazard probability reduced
  - Region 3: Hazard control desirable
  - Region 4: Hazard control not necessary

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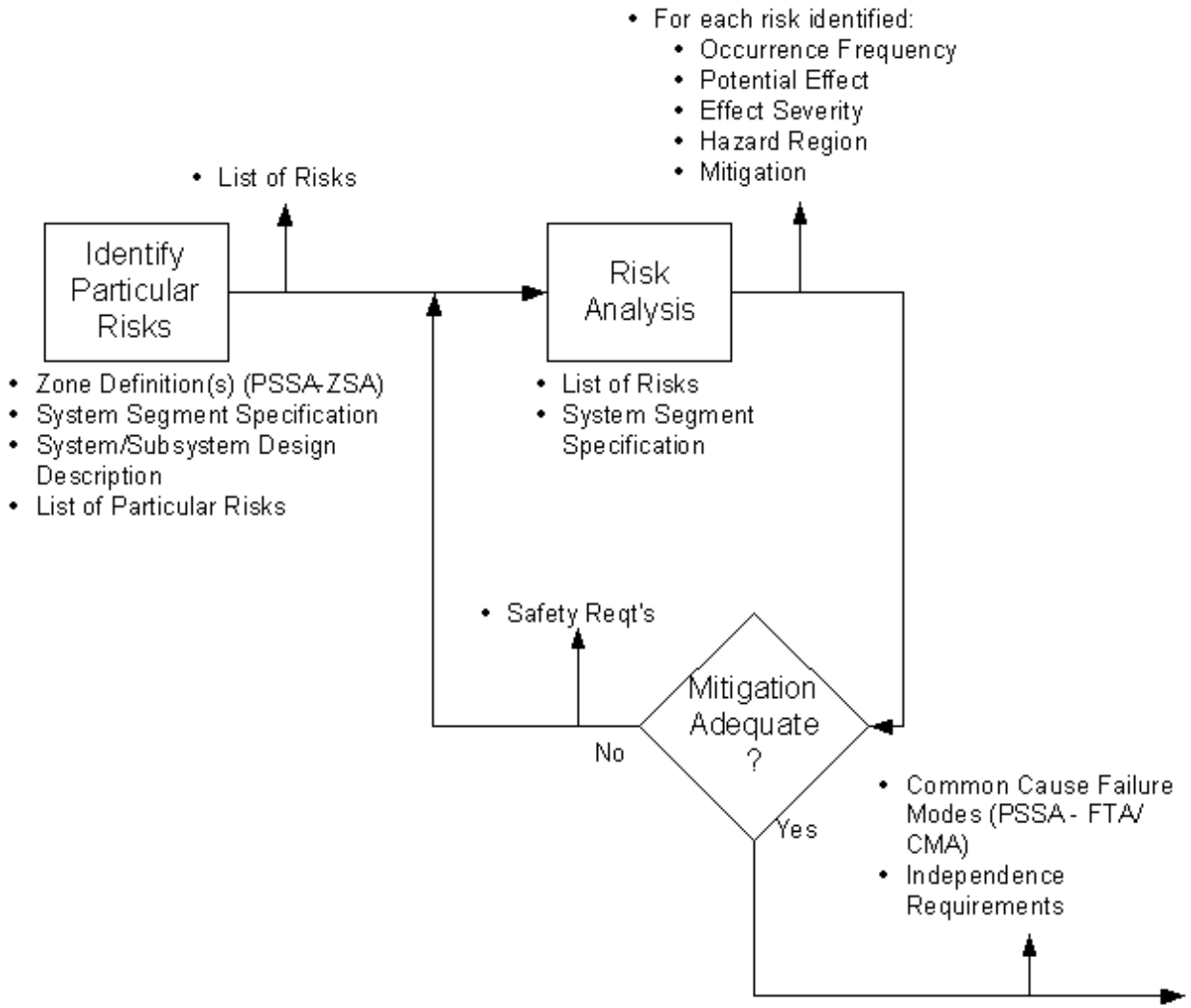
Safety Process – PSSA/PRA



Process Map

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Safety Process – PSSA/PRA

PRA Form

Particular Risk Analysis - DGPS (Zone 1)									
RISK ID NO.	PARTICULAR RISK DESCRIPTION	FREQ. RANK	EFFECT OF RISK ON SYSTEM	SEV. RANK	HAZ. REGION	SYSTEM MITIGATION	FREQ. RANK	SEV. RANK	HAZ. REGION
1-1									
1-2									

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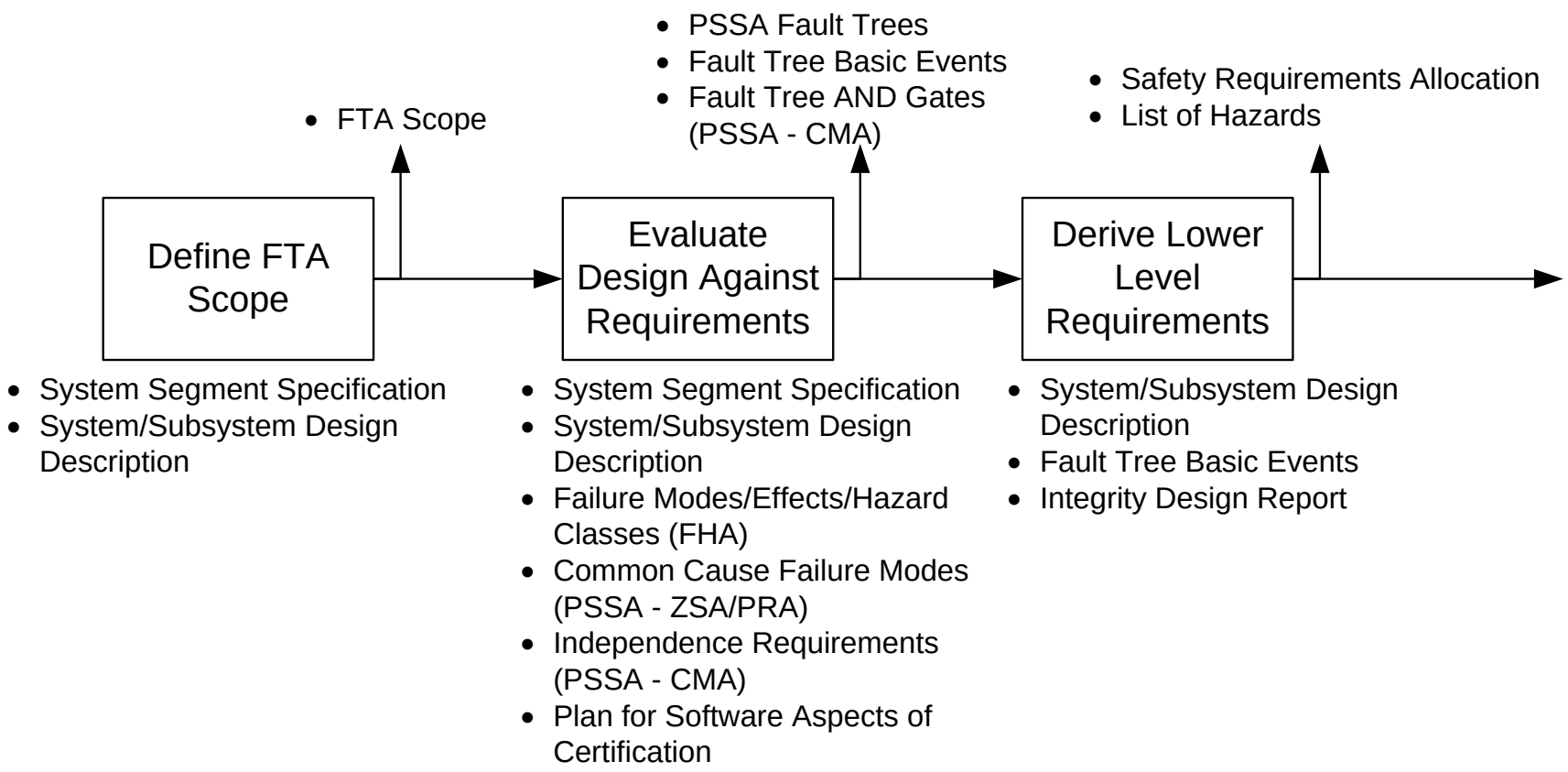
Safety Process – PSSA/FTA

FTA Process Map



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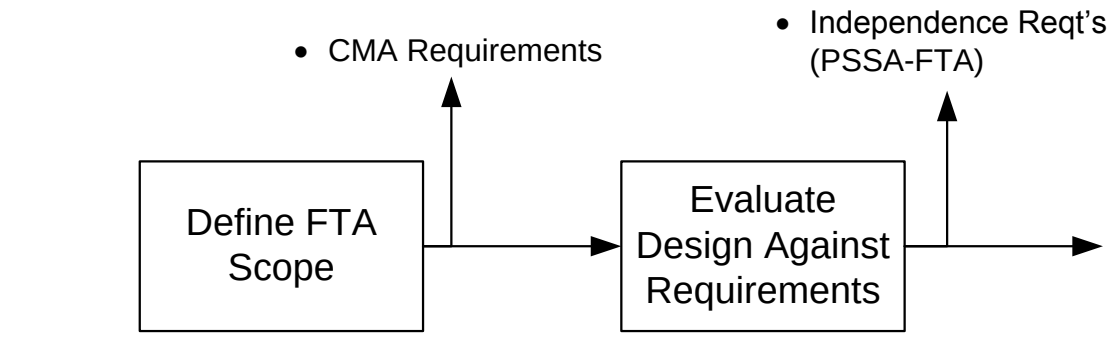
Safety Process – PSSA/CMA

CMA Process Map



- System Segment Specification
- System/Subsystem Design Description
- Fault Tree AND-Gates (PSSA-FTA)
- CMA Checklist

- CMA Requirements
- System Segment Specification
- System/Subsystem Design Description
- Common Cause Failure Modes (PSSA-ZSA/PRA)

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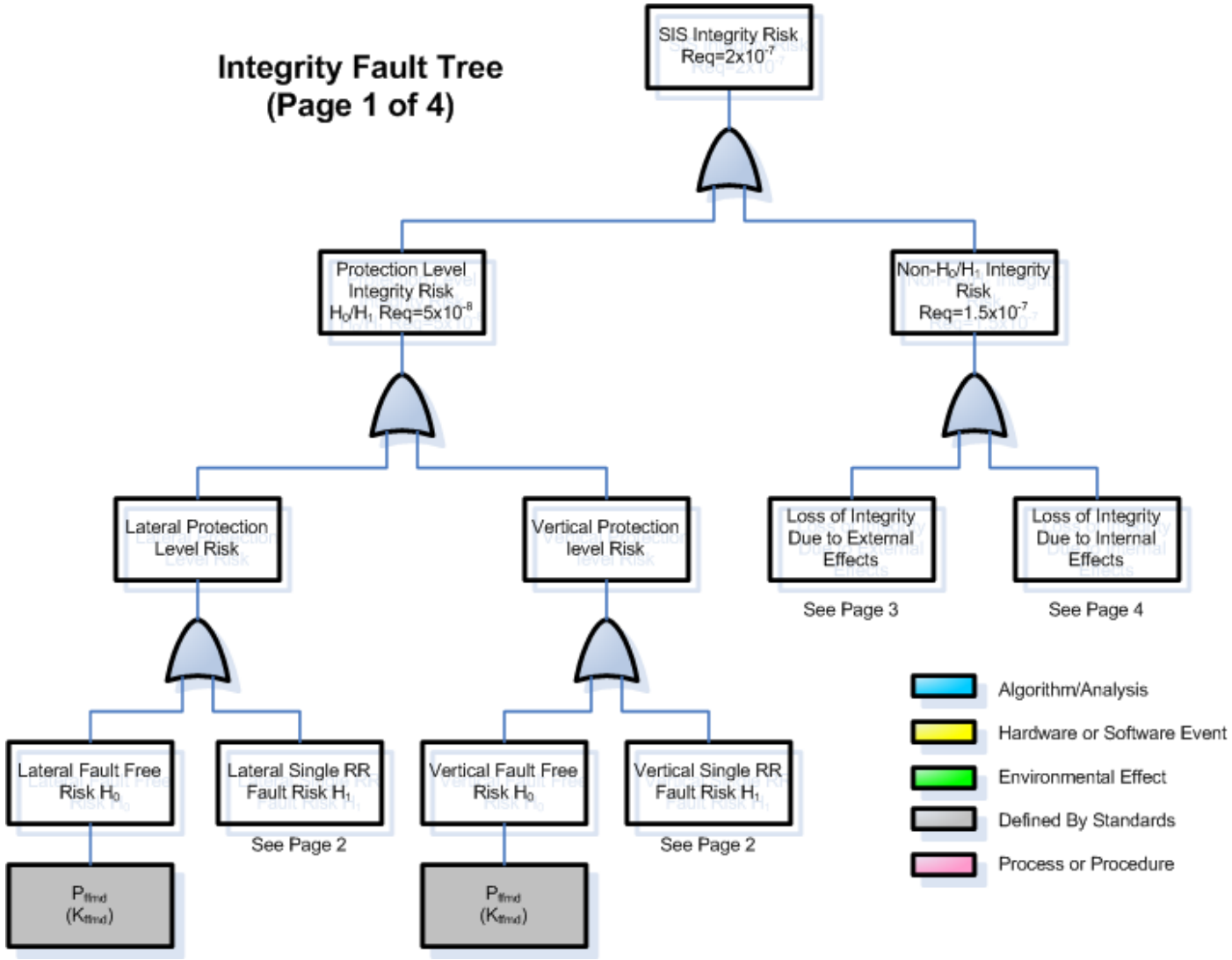
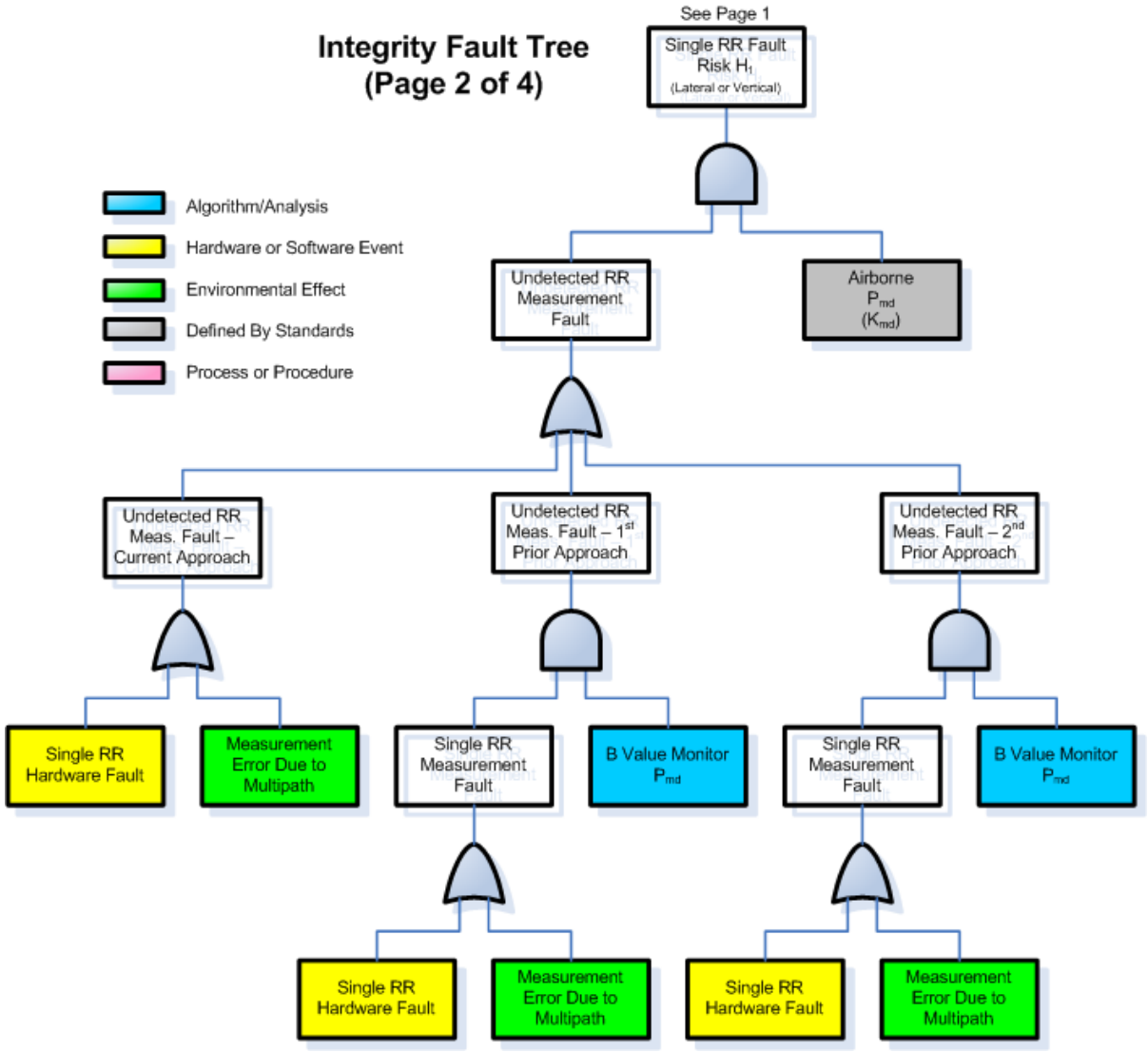
Safety Results – PSSA



Assessment Results are Published and Reviewed

Safety Results – PSSA



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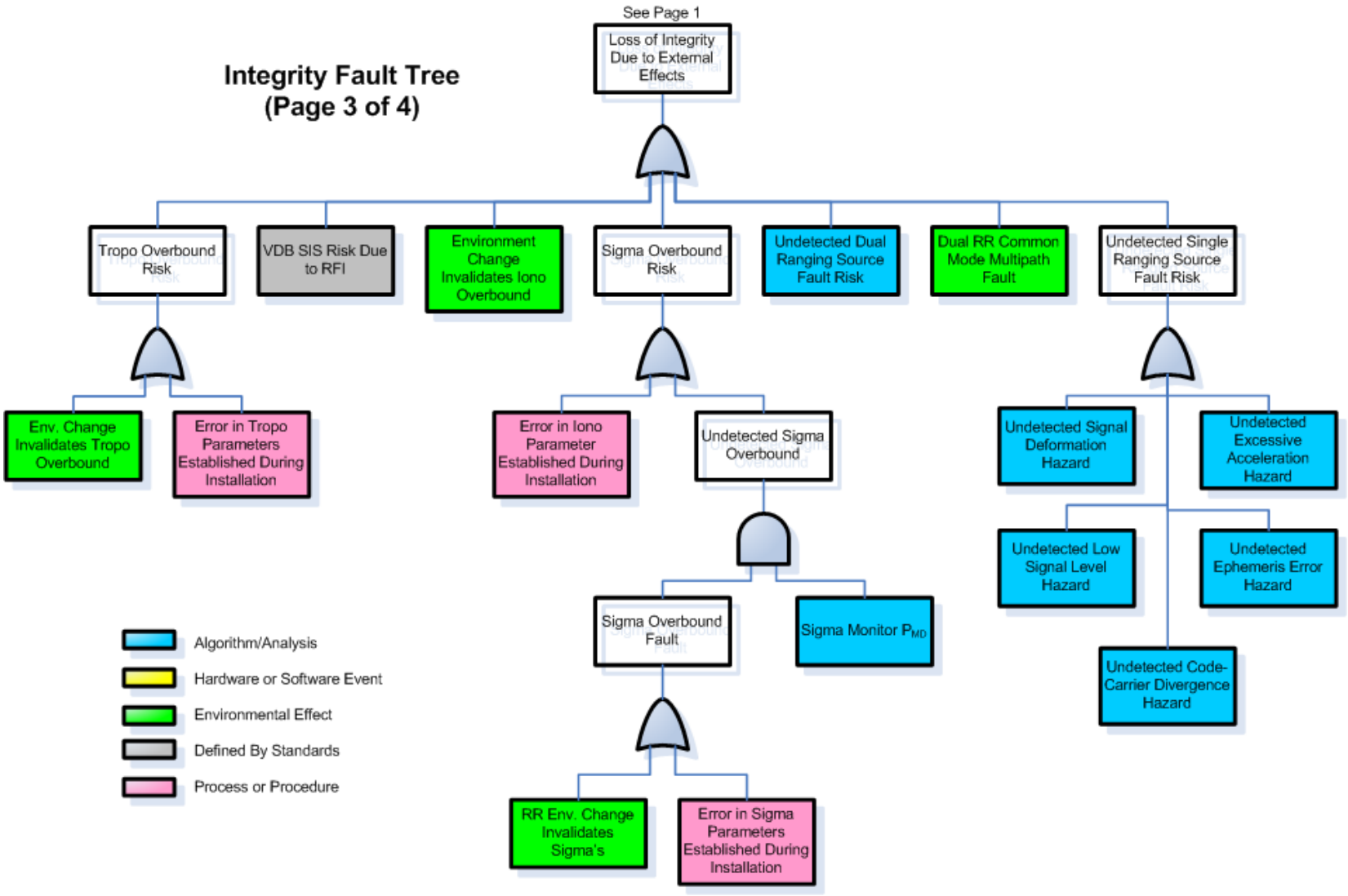
Safety Results – PSSA



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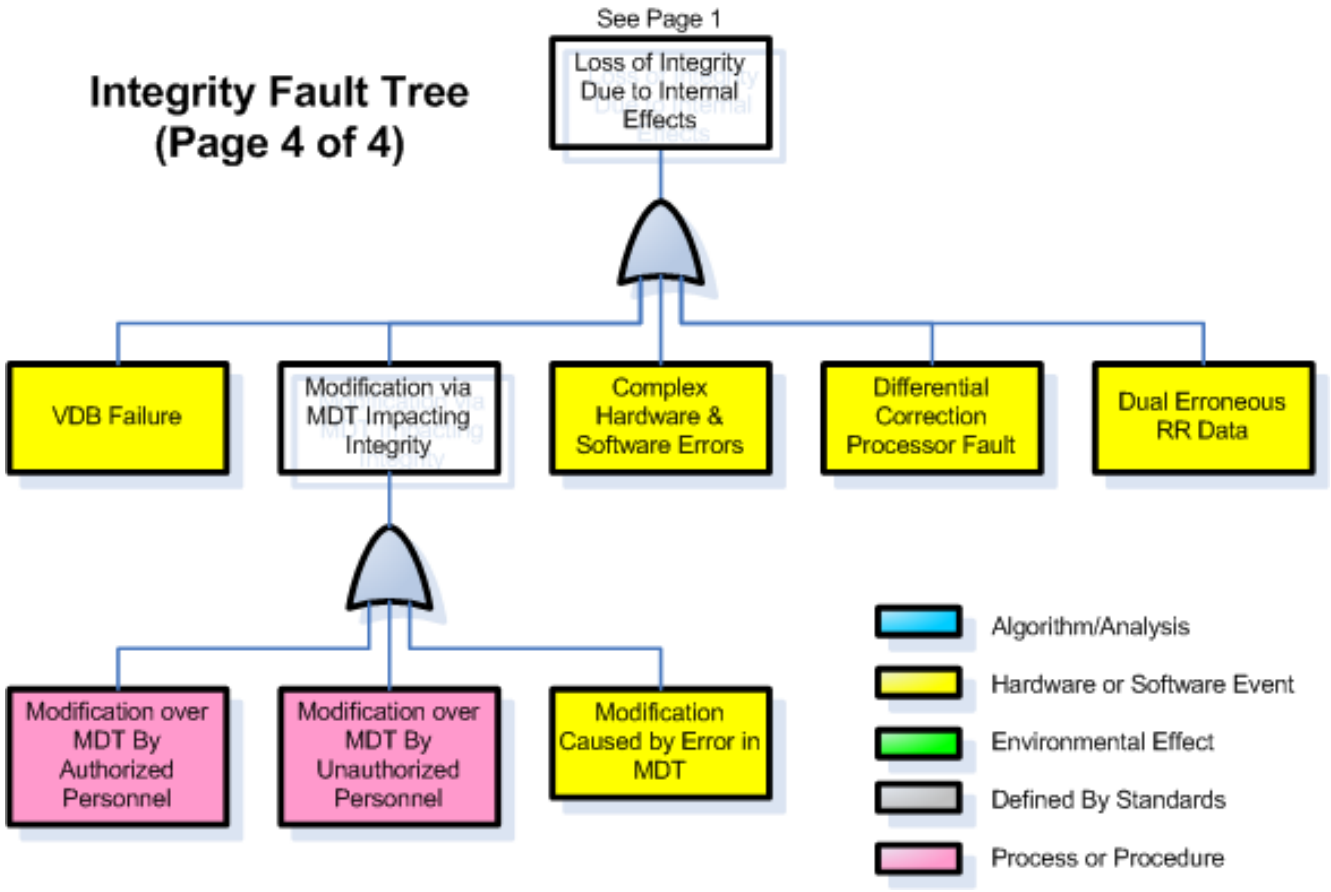
Safety Results – PSSA



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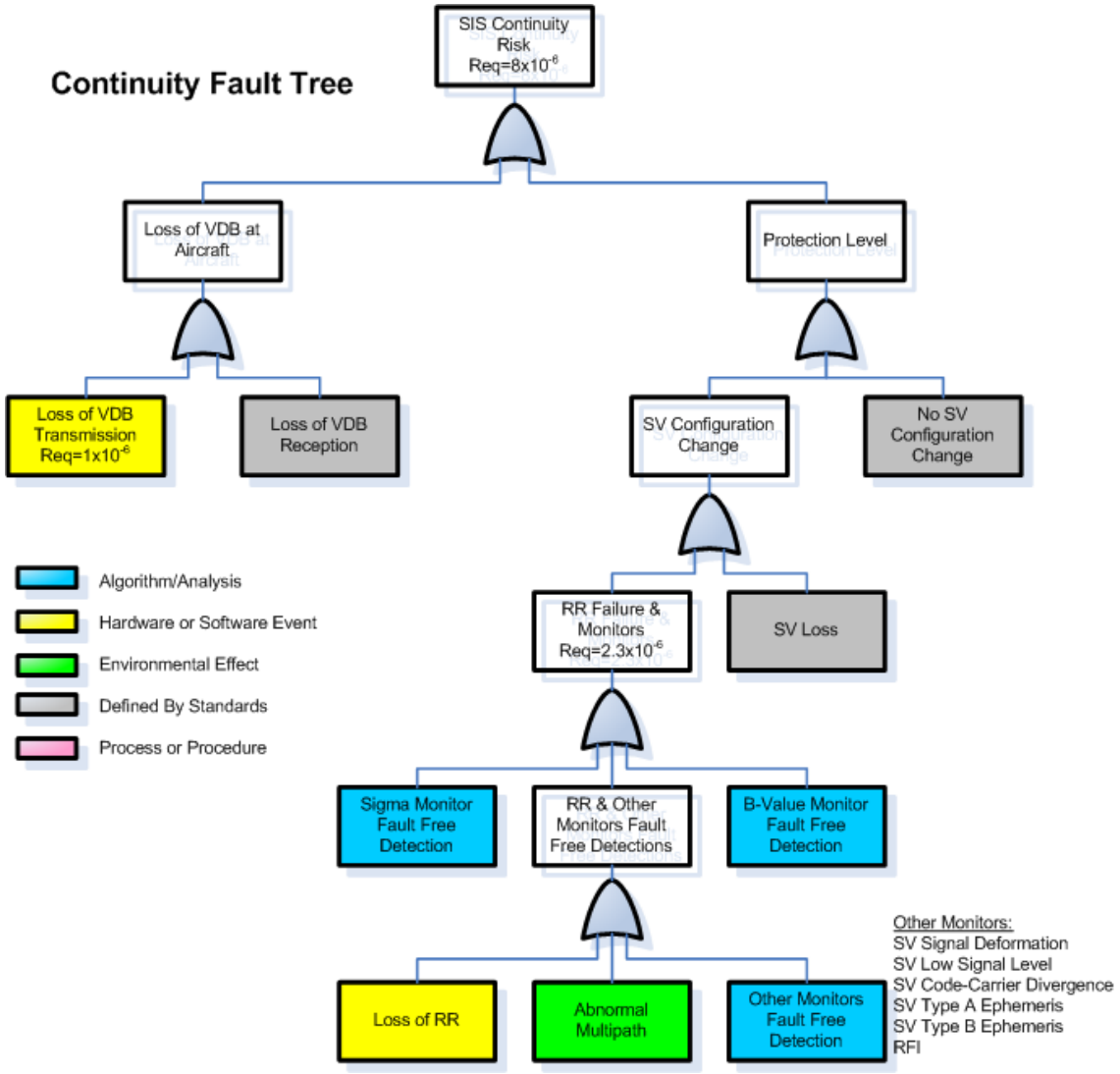
Safety Results – PSSA



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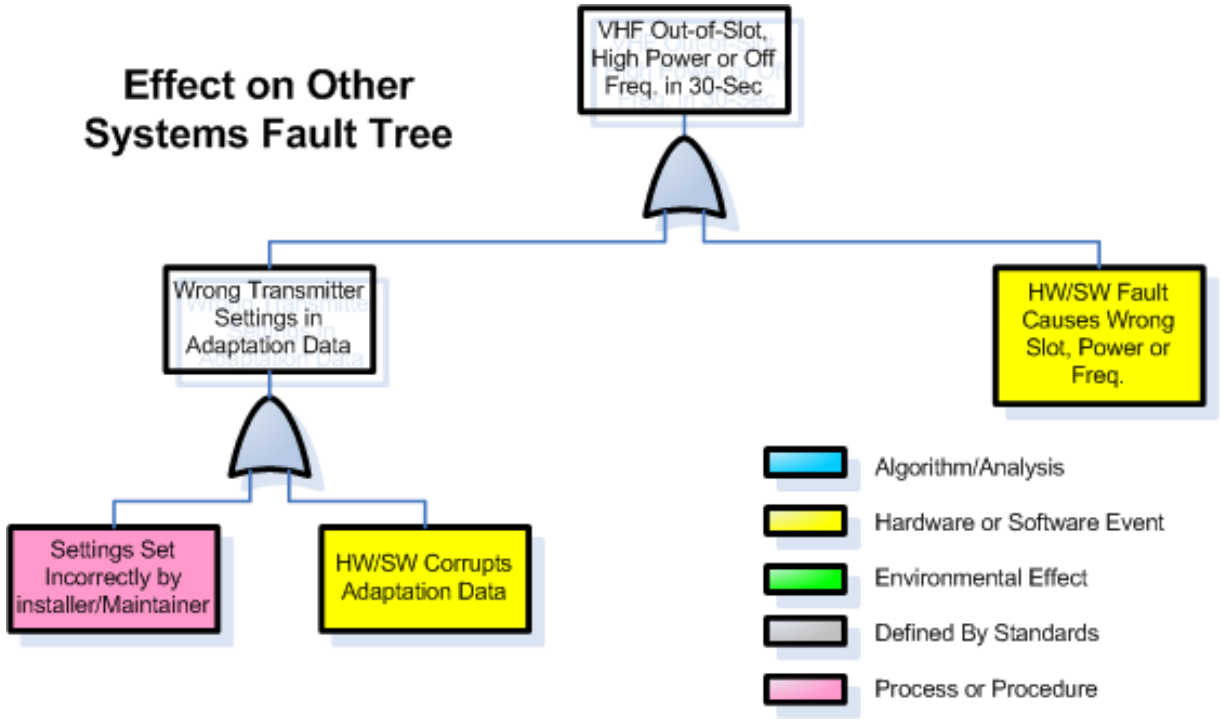
Safety Results – PSSA



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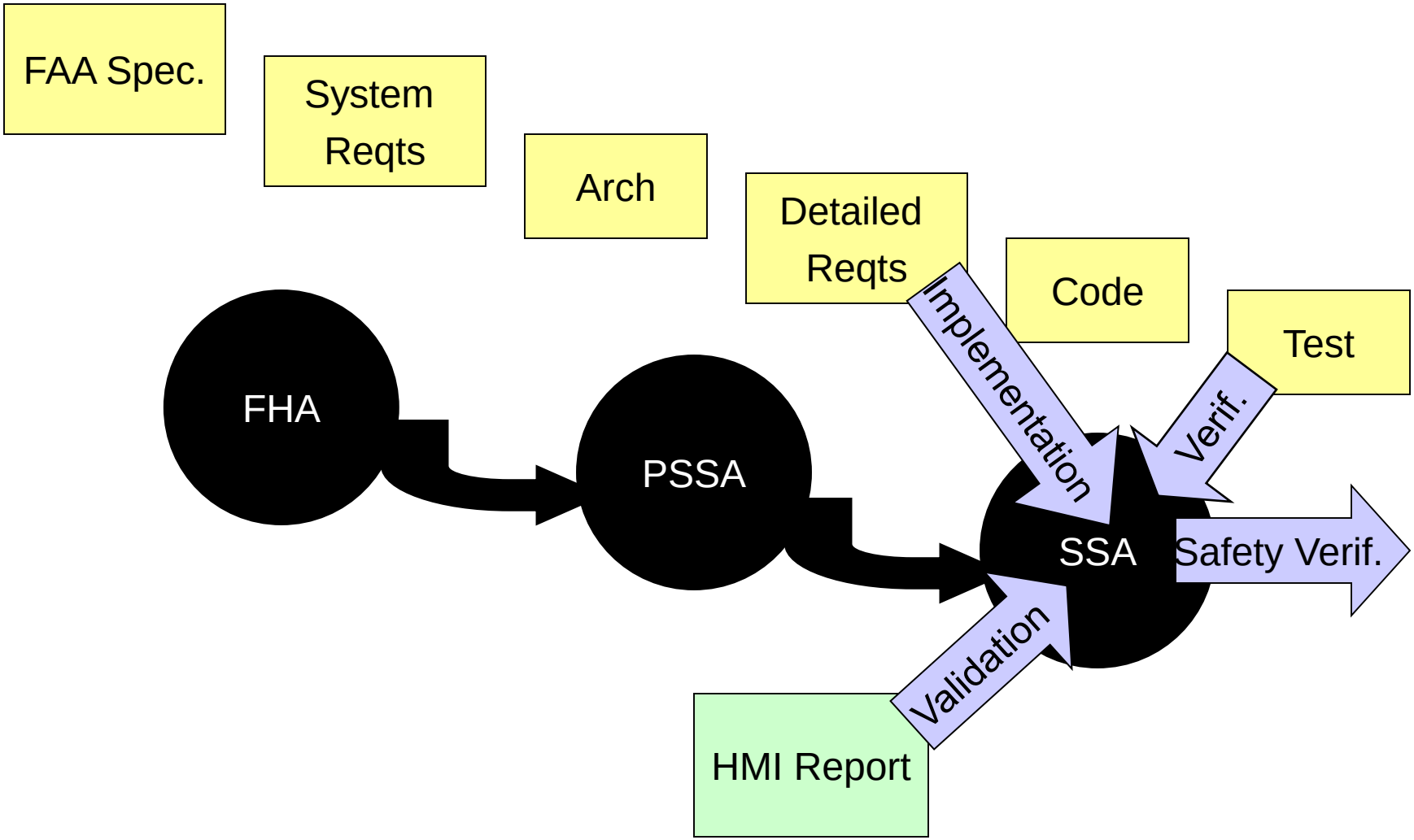
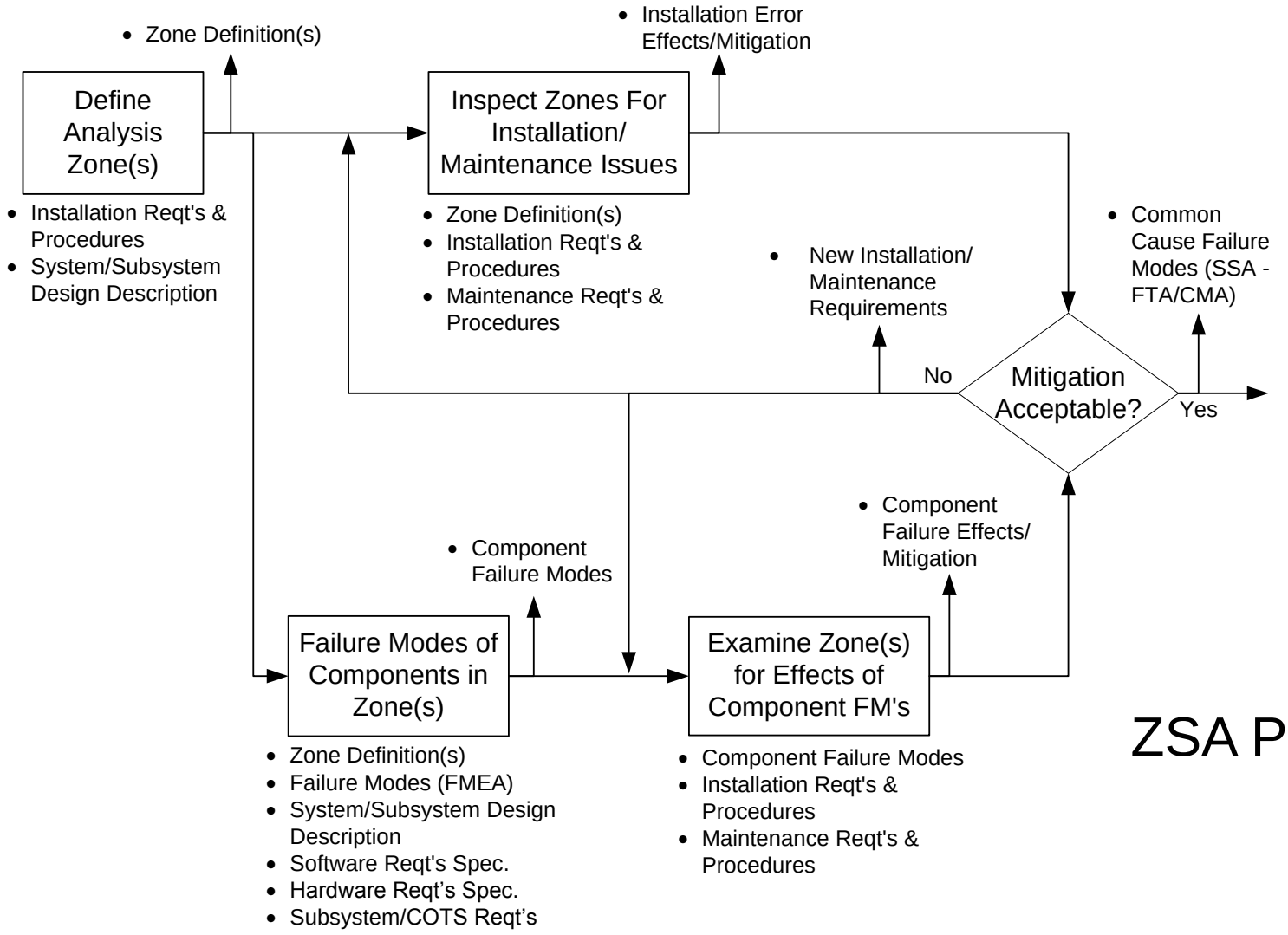
Safety Process - SSA



System Safety Analysis based on Detailed Requirements

Safety Process – SSA/ZSA



ZSA Process Map

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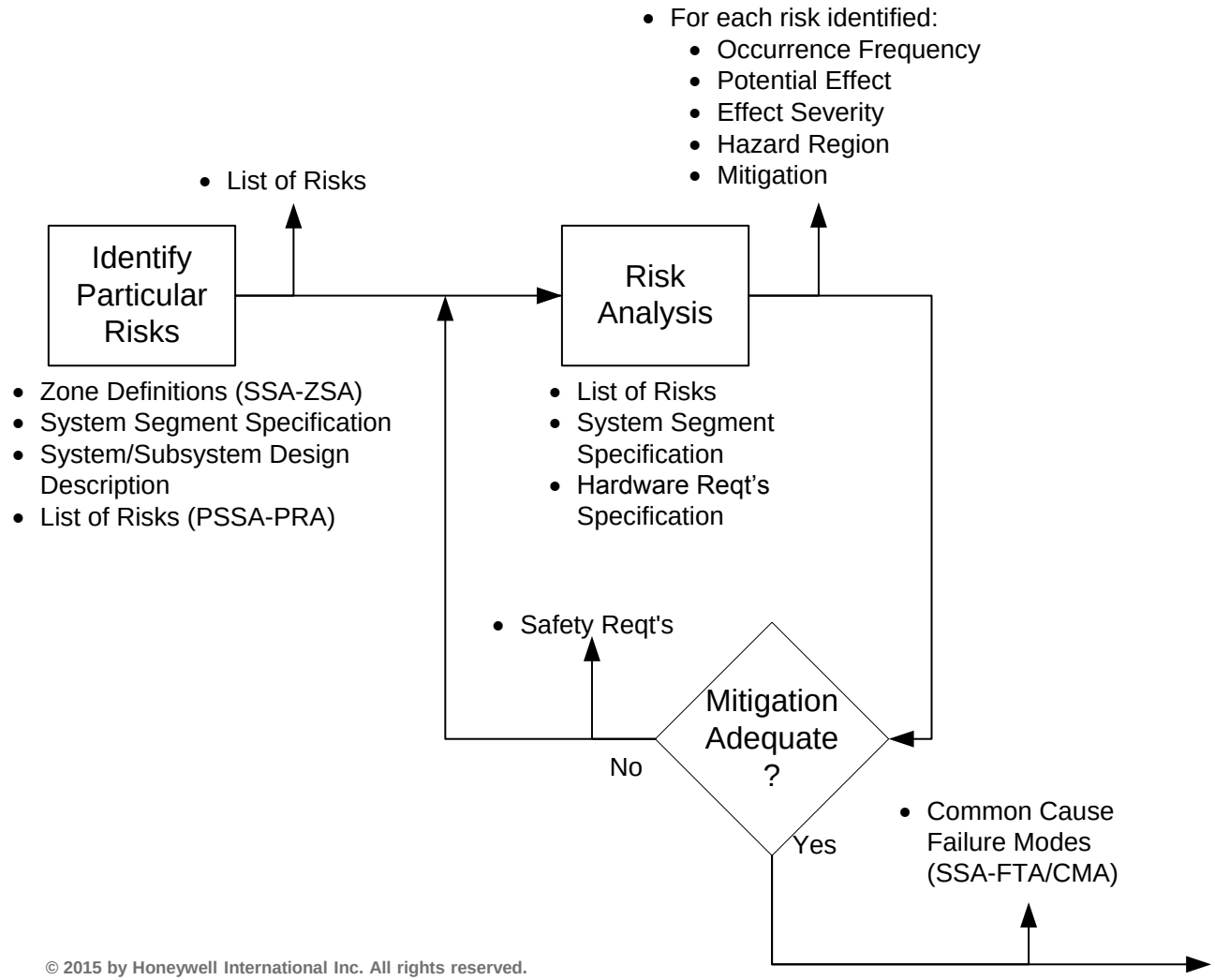
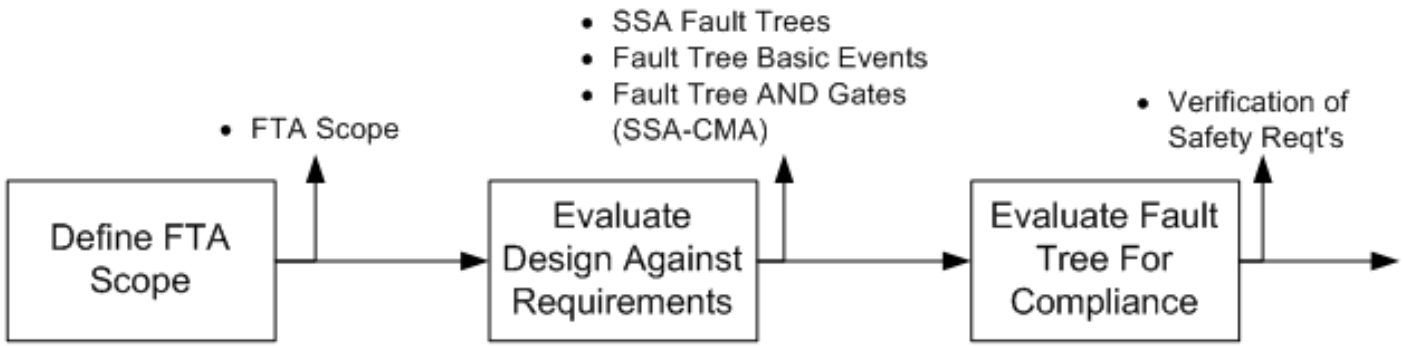
Safety Process – SSA/PRA



As in PSSA, Each SSA Assessment has a Process Map

Safety Process – SSA/FTA



- System Segment Specification
- System/Subsystem Design Description
- System Level Safety Reqt's (FHA, PSSA)

- System Segment Specification
- System/Subsystem Design Description
- Hardware Requirements Spec.
- Software Requirements Spec.
- Software Design Description (SDD)
- Subsystem/COTS Requirements
- Installation Guide
- Maintenance Manual
- Verification Documents
- Fault Trees (PSSA-FTA)
- Failure Modes/Effects/Detection/New Hazards (FMEA)
- Common Cause Failure Modes (SSA-ZSA/PRA)
- Independence Reqt's (SSA-CMA)
- Failure Modes/Failure Rates (FMEA)
- Reliability Prediction Report
- Fault Tree Basic Events
- Integrity Design Verification Analyses

- Minimal Cut Set Tool

FTA Process Map

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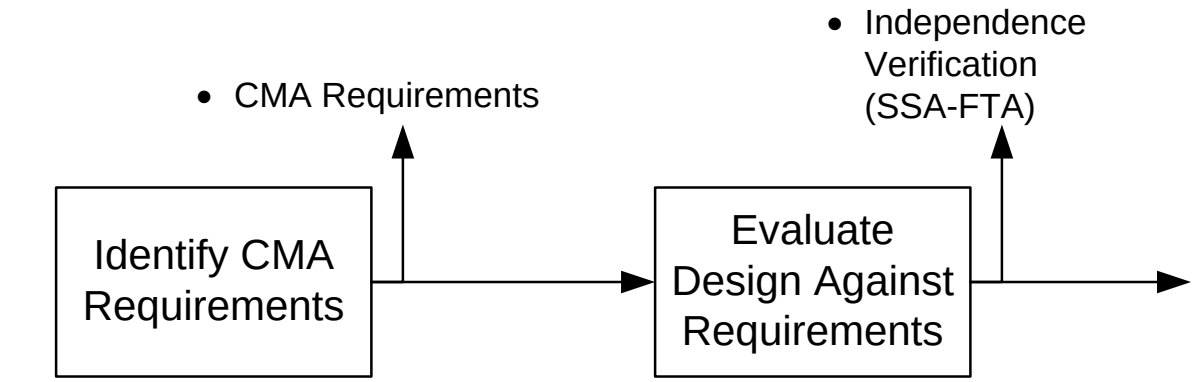
Safety Process – SSA/CMA



CMA Process Map

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Safety Process – Personal Safety

- Purpose: Analyze potential personal hazards with interfaces that could occur throughout the products life cycle including: operator, maintainer, installer and transportability.
- Program Requirements:
  - The FAA specification [15] stipulates that the ground subsystem is to meet the Personal Safety and Health requirements in section 3.3.5 of the Electronic Equipment, General Requirements document [17].
  - Honeywell elected to get a CE mark on the SLS-4000 which stipulates personal safety requirements.
- Approach
  - CE Mark compliance performed by independent party. Due to commonality with FAA requirement for personal safety, elected to include them with compliance being performed by independent party.

Safety Process – Personal Safety

- Requirements Overview (# of requirements)
  - General (7)
  - Electrical Safety (56)
  - Laser Radiation (3)
  - Switches (8)
  - Mechanical Hazards (13)
  - Markings, Signs, Tags and Symbols (46)
  - Hazardous and Restricted Materials (13)
  - Seismic Safety (6)
- Results – All applicable tests Passed
- The Personnel Safety Hazard Analysis Report [4] was prepared as part of the original Block 0 SDA program.

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SITING/INSTALLATION & SAFETY

- Many of the derived safety requirements identified in the SSA relate to installation or operational requirements (See SSA results).
- The derived safety requirements trace to an installation requirements book in the requirements database.
- Compliance with these requirements is shown by contents of one or more of the following documents:
  - GBAS Siting Plan [12]
    - Defines the processes for selecting an installation site for the Honeywell SLS-4000.
  - GBAS Measured Site Data (MSD) Process [11]
    - Defines the procedures and acceptance criteria for creating an installation specific Measured Site Data loadable binary file.
  - GBAS SLS-4000 Commercial Instruction Book [6]
    - Defines all procedures required for installation, operation and maintenance of the Honeywell SLS-4000.

Questions Asked:

- How the key performances requirements (Accuracy, Continuity, Availability, Integrity, Time to Alarm) are demonstrated to the SBAS/GBAS operator for acceptance ? Which means are used : collection of data, simulation,… ?—Please see preceeding pages
- How GBAS is handling ionosphere corrections around equator ? What are the challenges ?
  - Honeywell Block II software Provides Configurability Options
    - Allows for a user-defined iono threat model
      - Enables improved availability in all geographies
    - Allows for automatic user-defined GLS approach procedures for a specific time period
      - Motivated by low latitudes – Set up to broadcast only during specific time periods
- How unavailability of performances is communicated to the users ?
  - Monitor Vertical Protection limits based on threat model (developed from 12-month data collection and analysis)
  - Though no specific monitors to warn in GAST-C system, when number of satellites with acceptable signals drops below 5, SLS-4000 would not transmit an acceptable solution and aircraft will show GLS not available.
  - ATSU will show GBAS unavailable

Acronyms

- AL – Assurance Level
- ARP – Aerospace Recommended Practices
- ASCII – American Standard Code for Information Interchange
- ATSU – Air Traffic Status Unit
- BB – Broadband
- CCD – Code Carrier Divergence
- CE – Conformity European
- CI – Configuration Item
- CIB – Component Instruction Book
- CMA – Common Mode Analysis
- COTS – Commercial Off The Shelf
- CRC – Cyclic Redundancy Check
- DAL – Design Assurance Level
- DCP – Differential Correction Processor

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Acronyms

- EA – Excessive Acceleration
- EMI – Electromagnetic Interference
- FCM – Fault Containment Module
- FHA – Functional Hazard Assessment
- FM – Failure Modes
- FMEA – Failure Modes & Effects Analysis
- FT – Fault Tree
- FTA – Fault Tree Analysis
- GBAS – Ground-Based Augmentation System
- GPS – Global Positioning System
- HMI – Hazardously Misleading Information
- HW – Hardware
- ICAO – International Civil Aviation Organization

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Acronyms

- Kffmd – Fault Free Missed Detection K-factor
- Kmd – Missed Detection K-factor
- LAAS – Local Area Augmentation System
- LAN – Local Area Network
- LGF – LAAS Ground Facility
- LP – Low Power
- MDT – Maintenance Data Terminal
- Pffmd – Fault Free Missed Detection Probability
- Pmd – Missed Detection Probability
- PRA – Particular Risk Analysis
- PSSA – Preliminary System Safety Assessment
- RFI – Radio Frequency Interference
- RPDP – Robust Power Distribution Panel
- RR – Reference Receiver

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Acronyms

- SAE – Society of Automotive Engineers
- SARPS – Standards and Recommended Practices
- SDA – System Design Assurance
- SDM – Signal Deformation Monitor
- SIS – Signal-in-Space
- SLS – Satellite Landing System
- SSA – System Safety Assessment
- SV – Satellite Vehicle
- SW – Software
- TDMA – Time Division Multiple Access
- TX – Transmitter
- VDB – VHF Data Broadcast
- VSWR – Vertical Standing Wave Ratio
- ZSA – Zonal Safety Analysis

Honeywell