Application of causal analysis based on systems theory (CAST) to regulatory decision-making: A case study of the Sikorsky S92A

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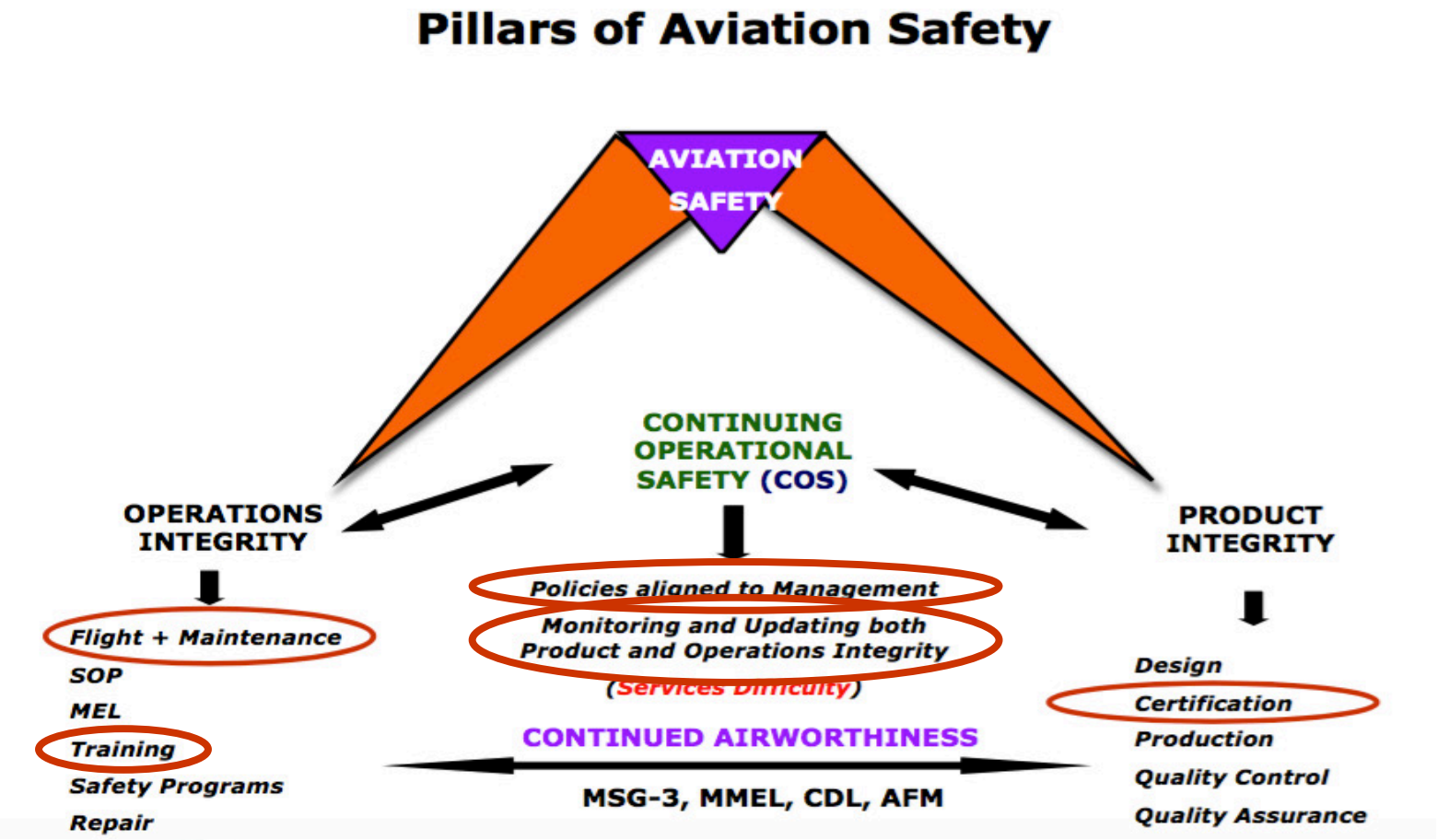
Agenda

- Introduction
- Regulation Analysis
- CAST Analysis
- Conclusions

Introduction



Source: https://doi.org/10.1016/j.ast.2024.109708

Regulation Analysis

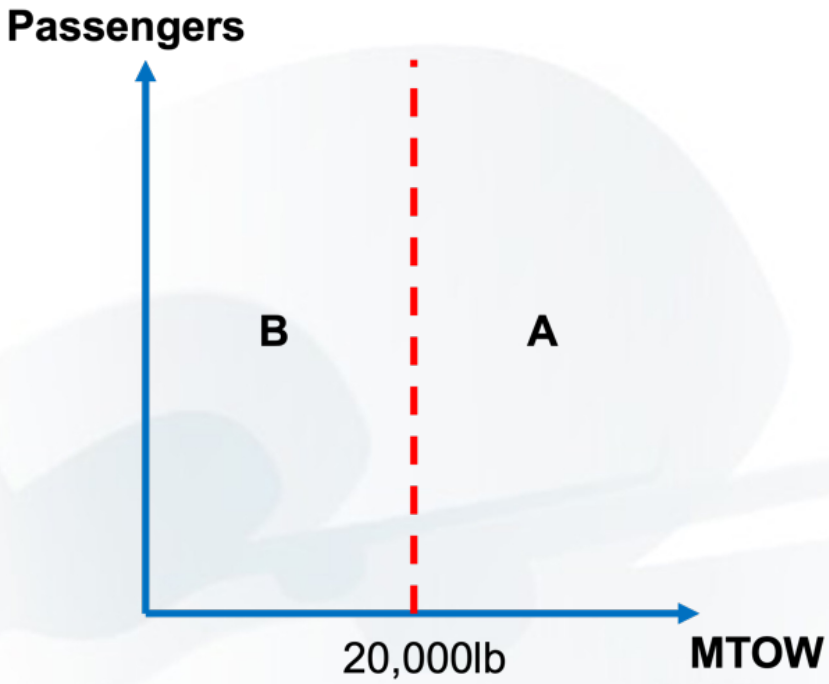


Figure (a) – Original certification categories based on 14 CFR Part 29.

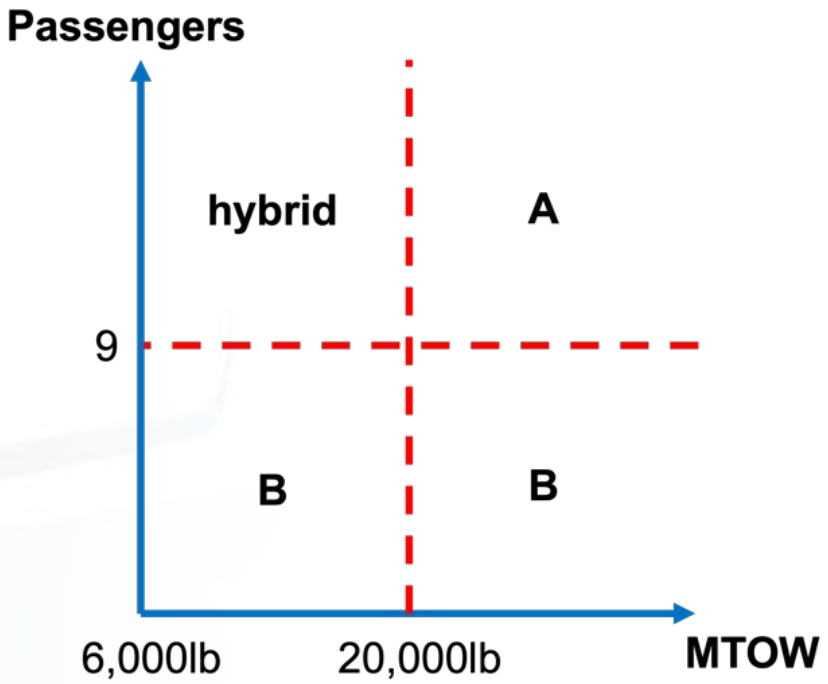


Figure (b) – Certification categories based on FAA Part 29 Amendment 29-21, item 29.1.

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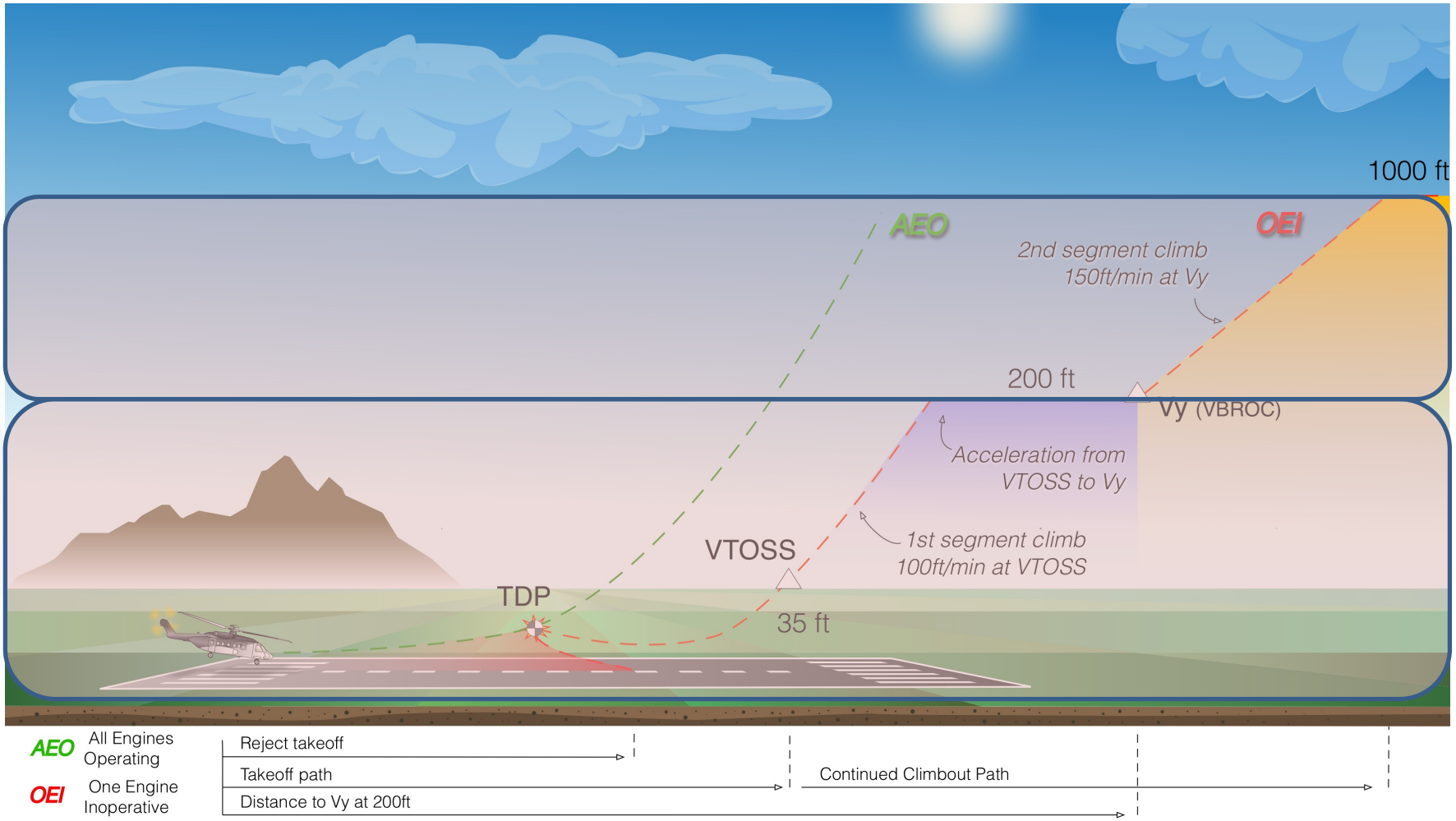
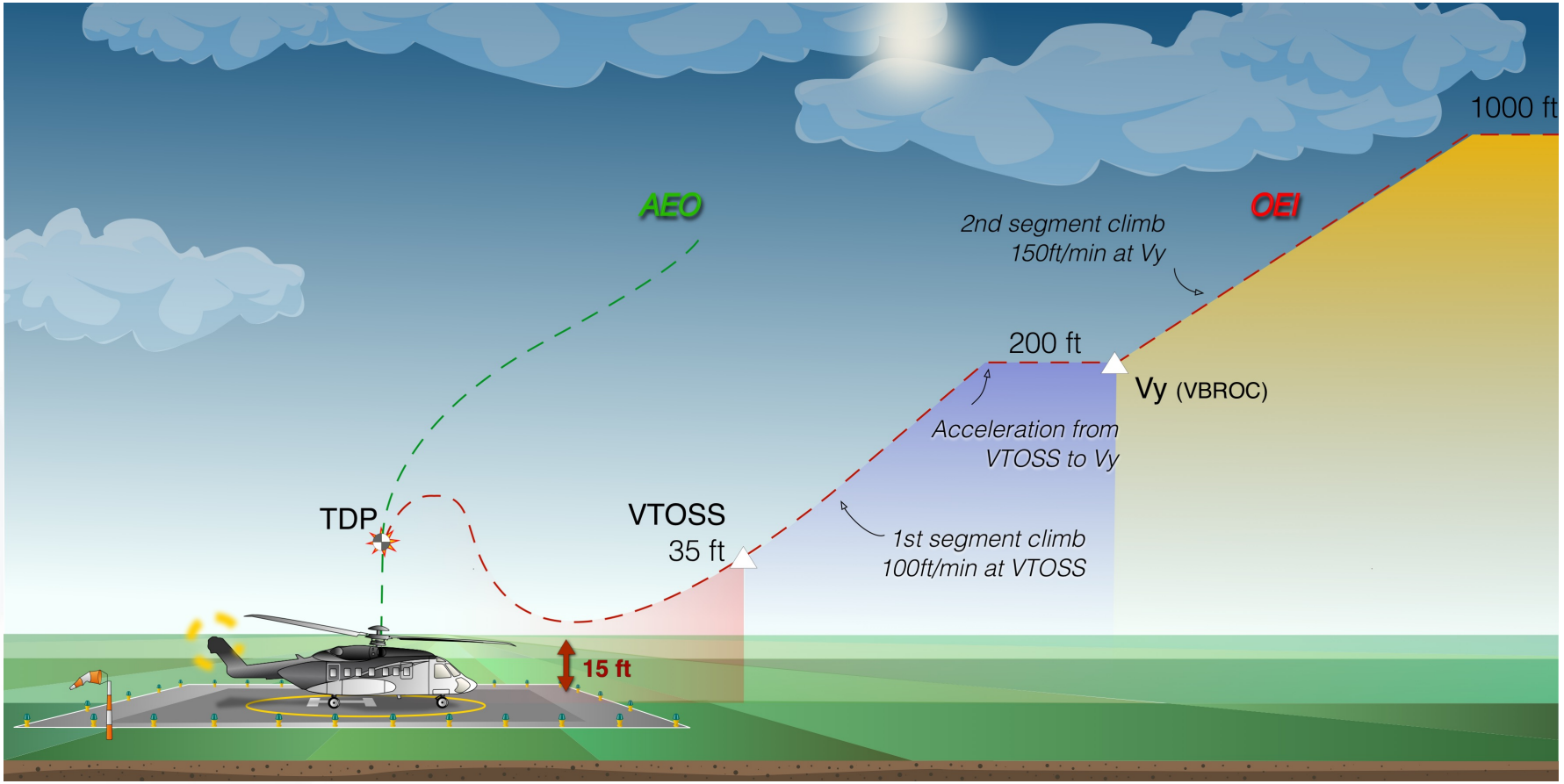
Regulation Analysis



FAA Part 29 Terminology – Category A Takeoff Profile (clear area)

Regulation Analysis



FAA Part 29 Terminology – Category A Takeoff Profile (ground heliport)
Source: https://doi.org/10.1016/j.ast.2024.109708

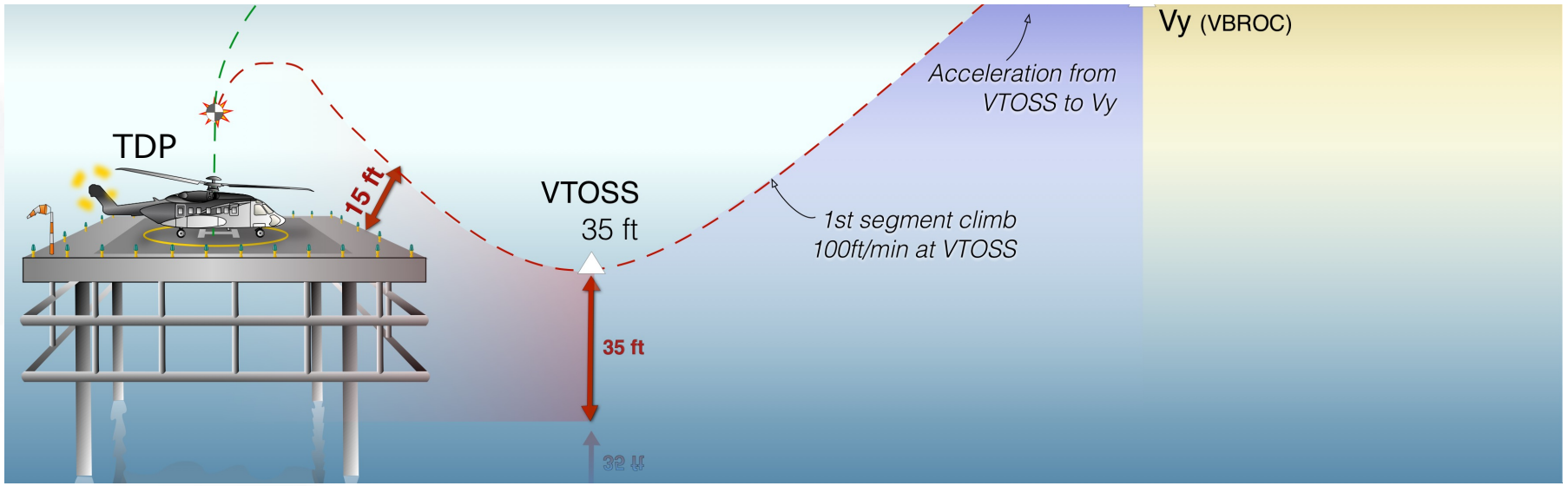
Regulation Analysis

GM1 CAT.POL.H.310(c) & CAT.POL.H.325(c) Take-off and landing

ED Decision 2014/015/R

(f) **Pilot reaction times**

(1) Pilot reaction time is an important factor affecting deck edge clearance in the event of an engine failure prior to or at RP. Simulation has shown that a delay of 1 second can result in a loss of up to 15 ft in deck edge clearance.



FAA Part 29, §29.60 Terminology – Category A Takeoff Profile (elevated heliport)
Source: https://doi.org/10.1016/j.ast.2024.109708

Regulation Analysis

Part 2, Section III
SUPPLEMENTAL PERFORMANCE DATA S-92

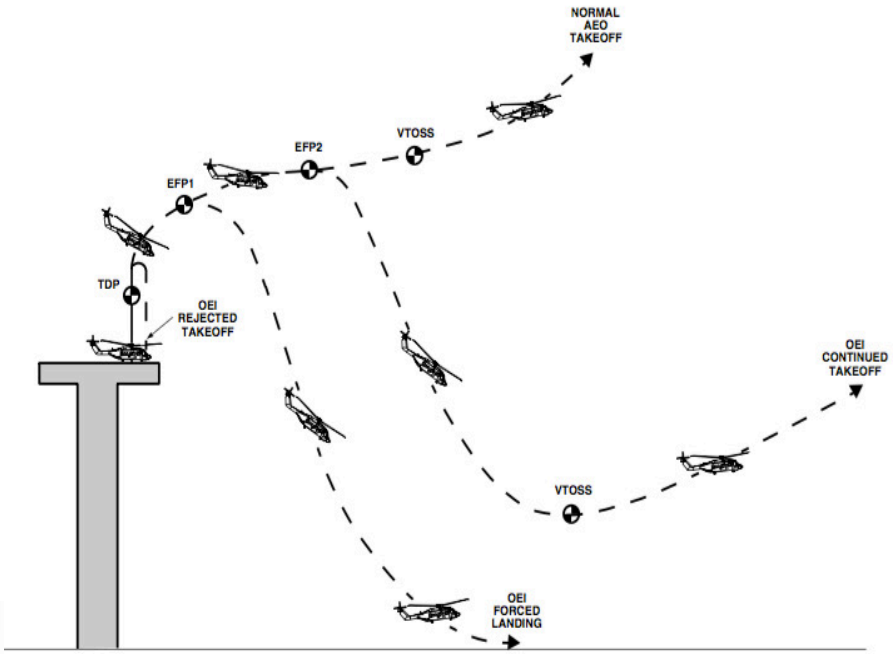
OPERATIONAL PERFORMANCE DATA

This section provides the performance information necessary to comply with the Operating Rules set forth by the various Regulatory Authorities.

Operators are responsible for obtaining operational approvals from their cognizant National Aviation Authority.

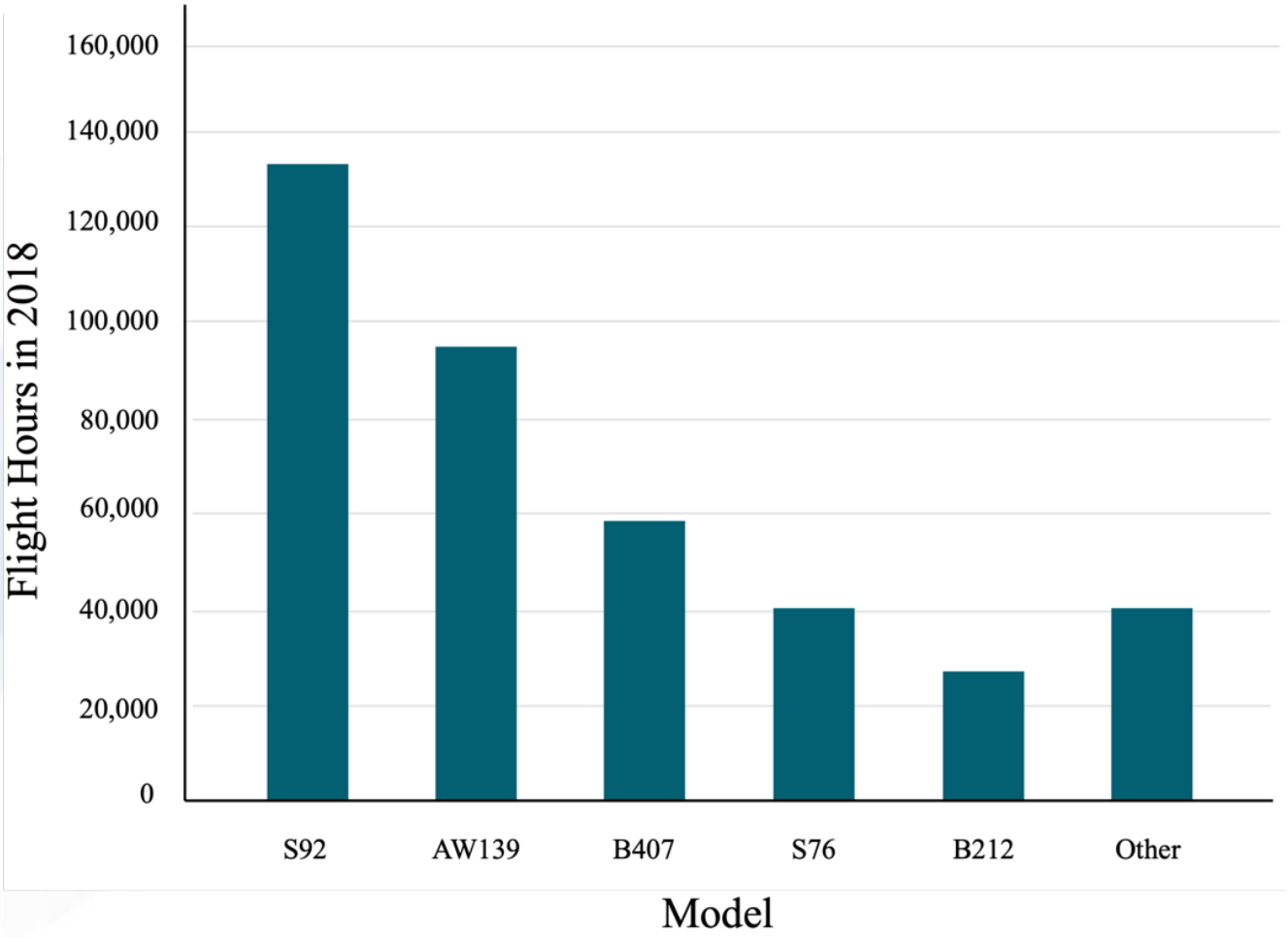
The AEO takeoff power HIGE WAT curve is shown in Part 1, Section I, Figure 1-3.

ELEVATED HELIDECK TAKEOFF PROFILE



(RFM S92A, Part 2, page III-1-50 and 52)

Regulation Analysis



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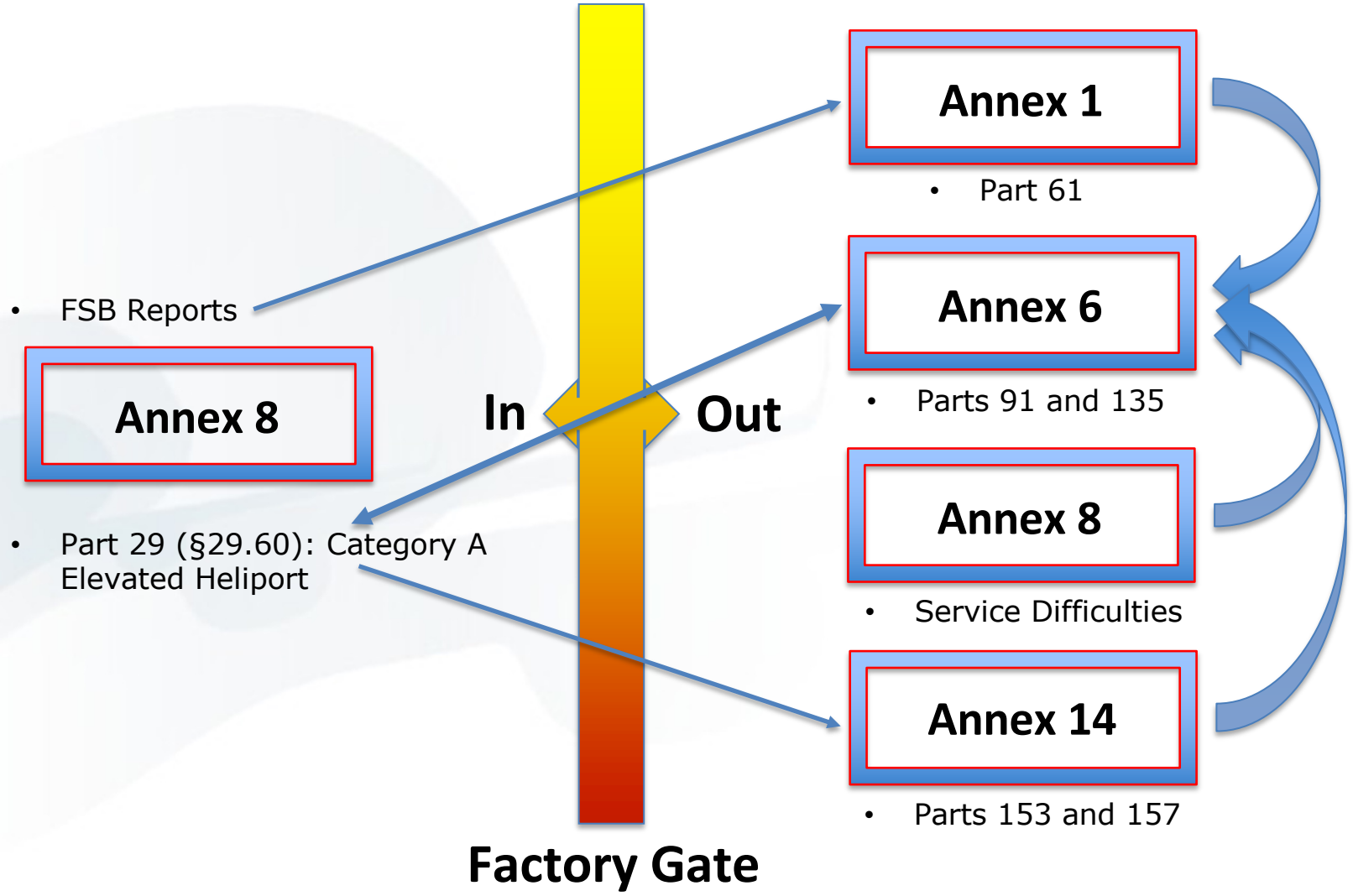
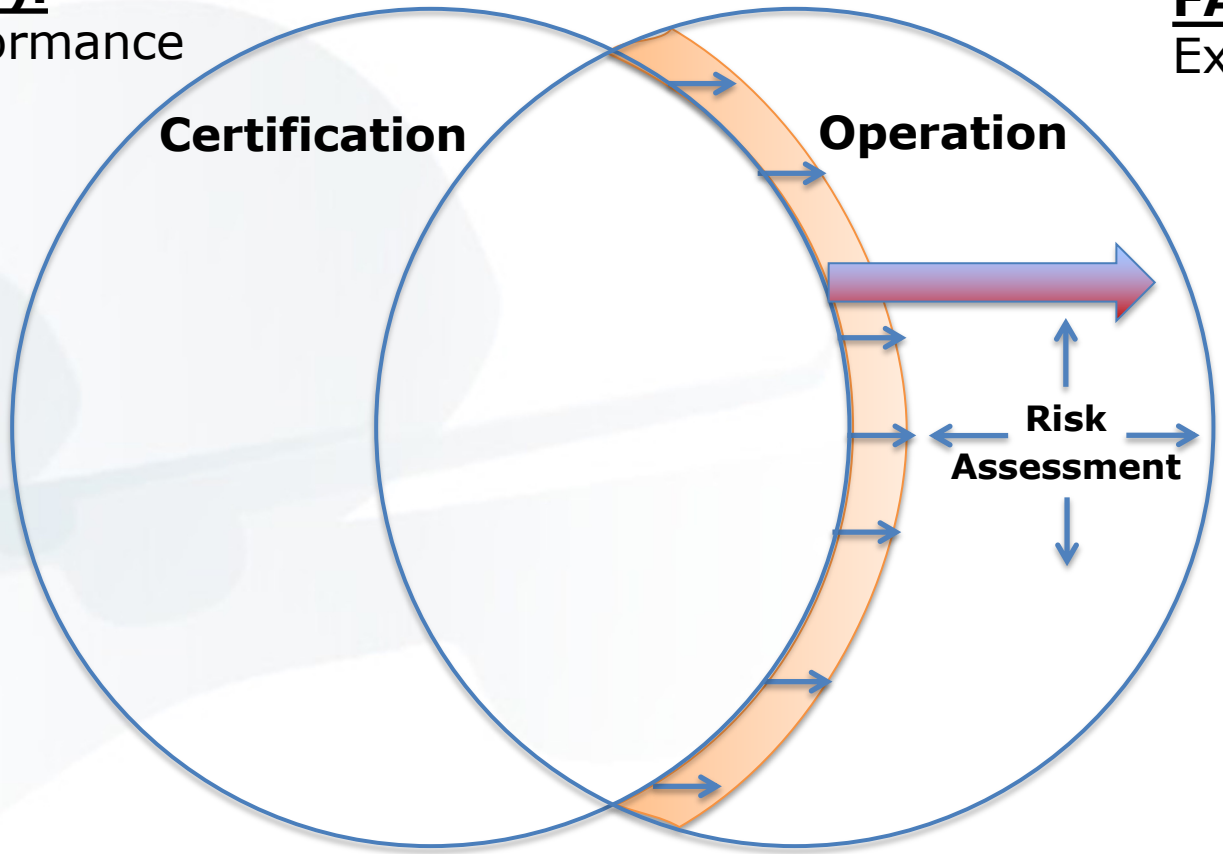
Regulation Analysis



Regulation Analysis

EASA (ICAO):
Code of Performance

FAA:
Exemptions



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CAST Analysis

Service Difficulty Report:

"(CAN) NR 2 ENGINE FAILED WHILE IN THE HOVER, OVER THE RUNWAY, JUST PRIOR TO ROTATING FOR THE TAKEOFF. THE ACFT WAS LANDED. THE RT SEAT PILOT HEARD 2 QUICK POPS AND NOTICED THE TGT ON NR 2 RISE JUST PRIOR TO ENGINE FAILURE. THE WEATHER WAS SKY CLEAR WITH WINDS APPROXIMATELY 300 AT 10 KNOTS AND TEMPERATURE 13. THE ACFT WAS TAXIED BACK TO THE RAMP WITHOUT FURTHER INCIDENT."

CAST Analysis

System Hazard 1: Aircraft loses ability to remain airborne

Safety Constraints:

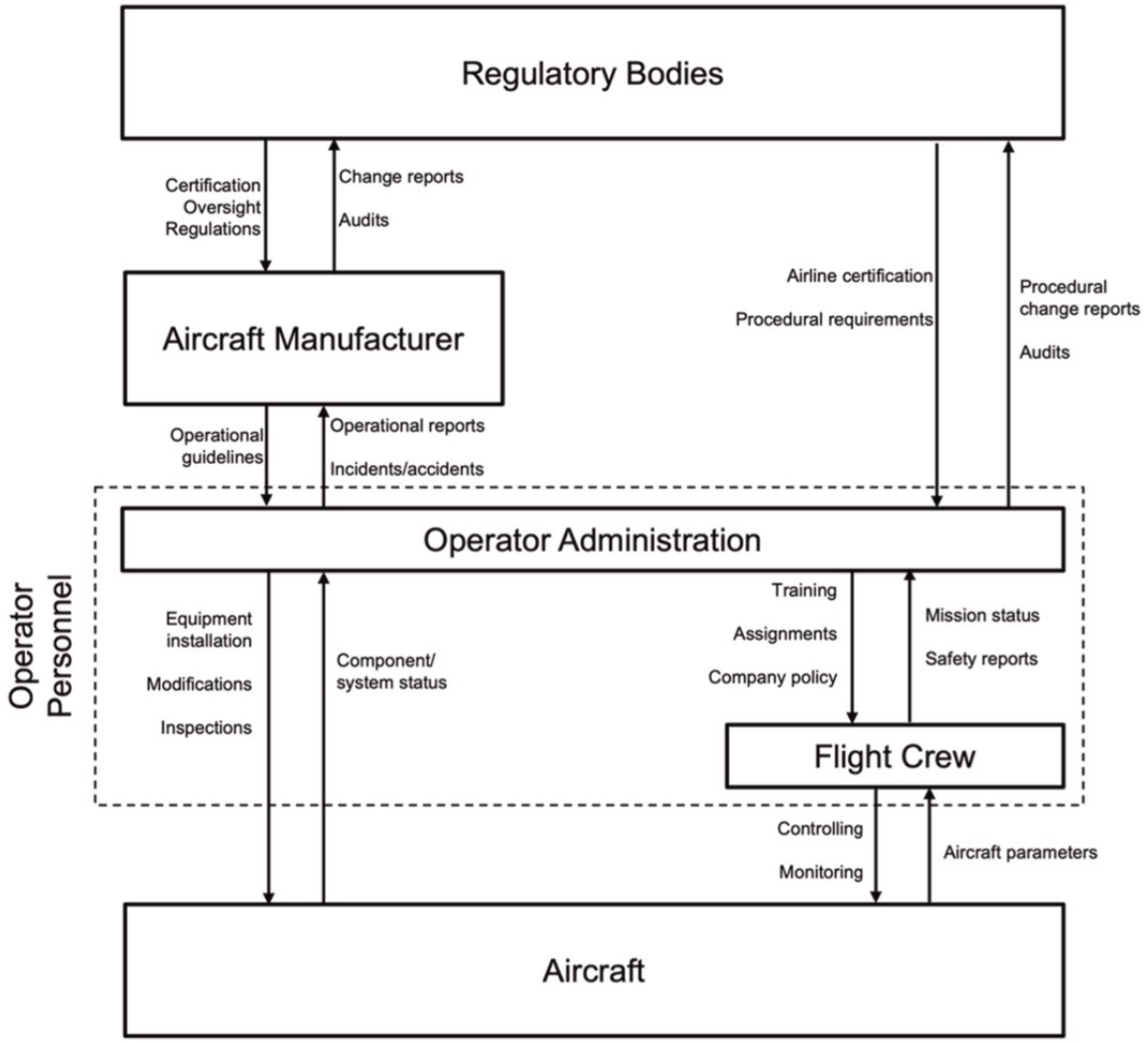
- Aircraft must have sufficient performance to remain airborne with critical engine inoperative
- Aircraft must be able to detect and recover from condition in which it does not have sufficient performance to remain airborne

System Hazard 2: Aircraft does not maintain adequate separation from outside objects

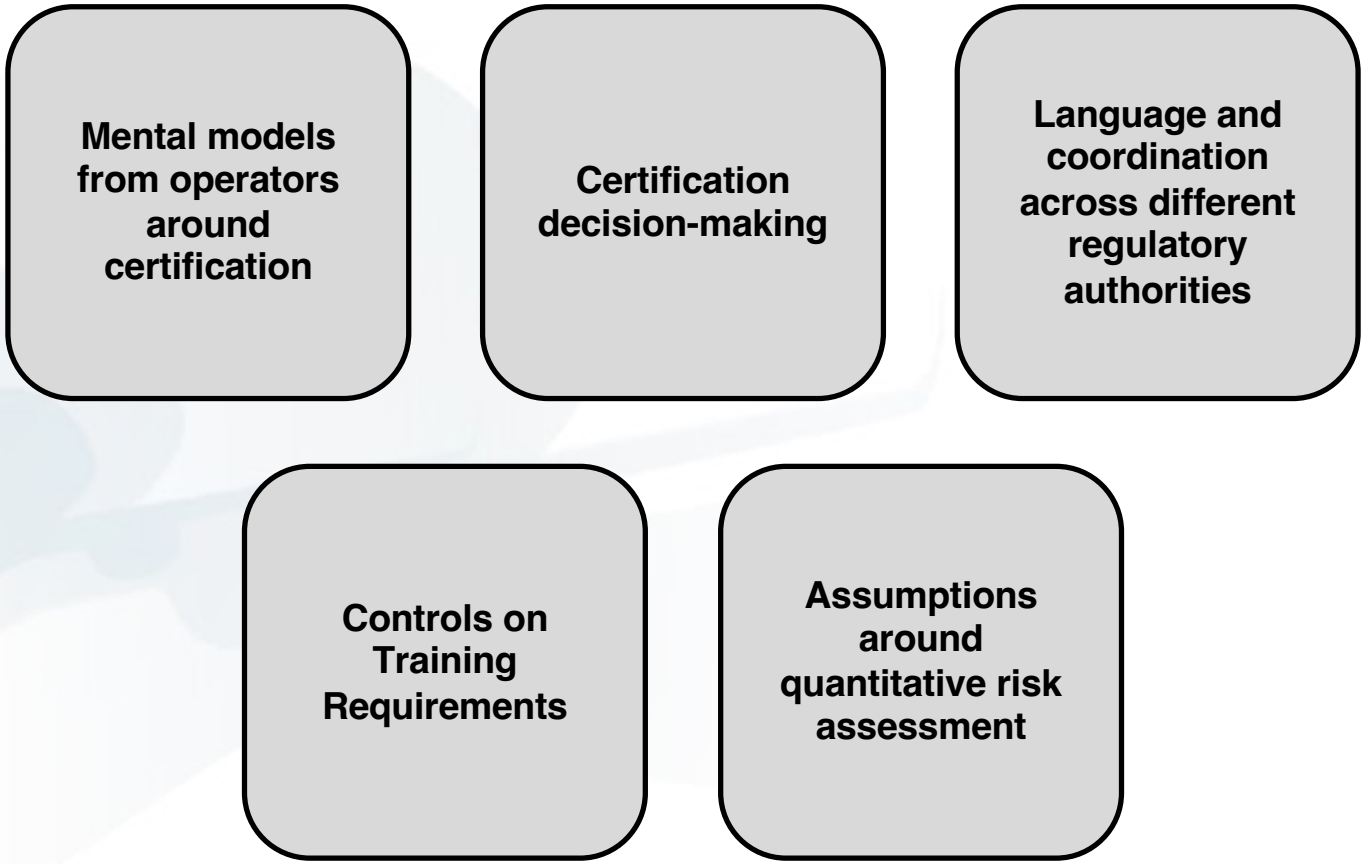
Safety Constraints:

- Aircraft must maintain adequate separation from outside objects
- Aircraft must be able to detect and recover from a violation of adequate separation

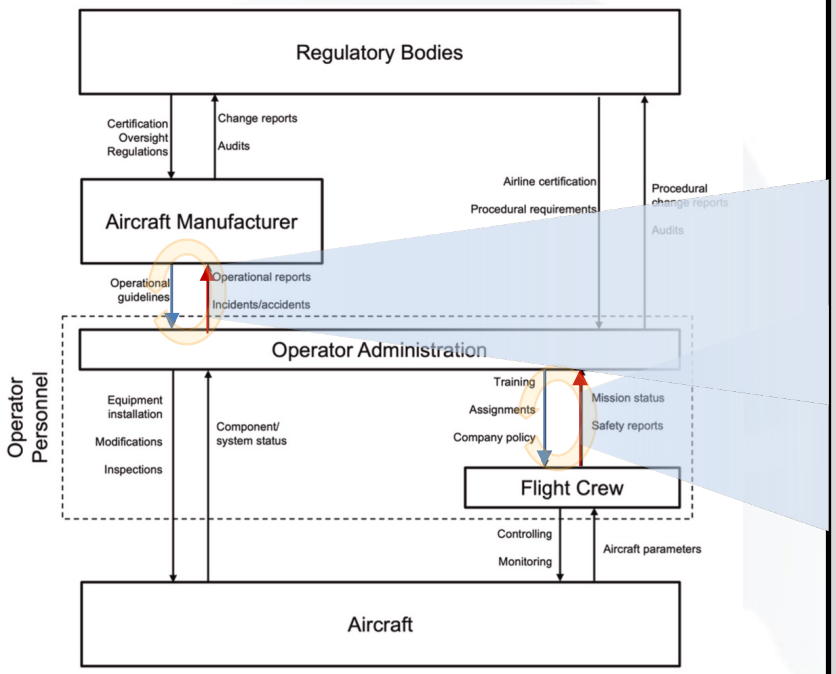
CAST Analysis



CAST Analysis



CAST Analysis



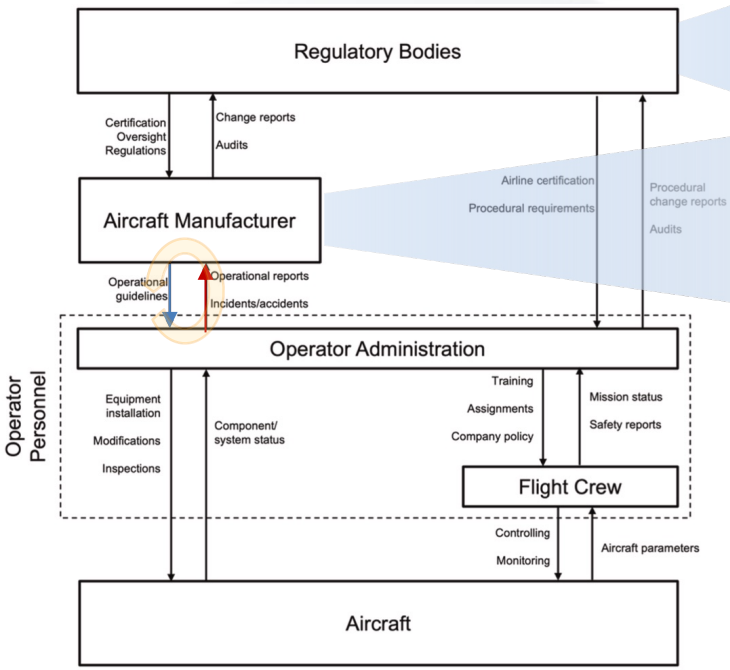
A Common Flawed Mental Model:

- Asked 50+ pilots of S92A: “Is the helicopter you fly certified / approved for elevated helideck operations?” **All respondents answered “Yes”**

Why?

- Rotorcraft Flight Manual (RFM) contains helideck operations procedures, so **it appears certified**
- HOWEVER, these procedures are in an **uncertified portion** of RFM (Part 2)
- Unlike typical RFM, Part 2 has **no explicit statement** that it is certified by the FAA (because it wasn’t)
- ***Recommendation 1:*** Ensure that certified and uncertified materials, systems, and processes are clearly distinguished to flight crews and mission planners.

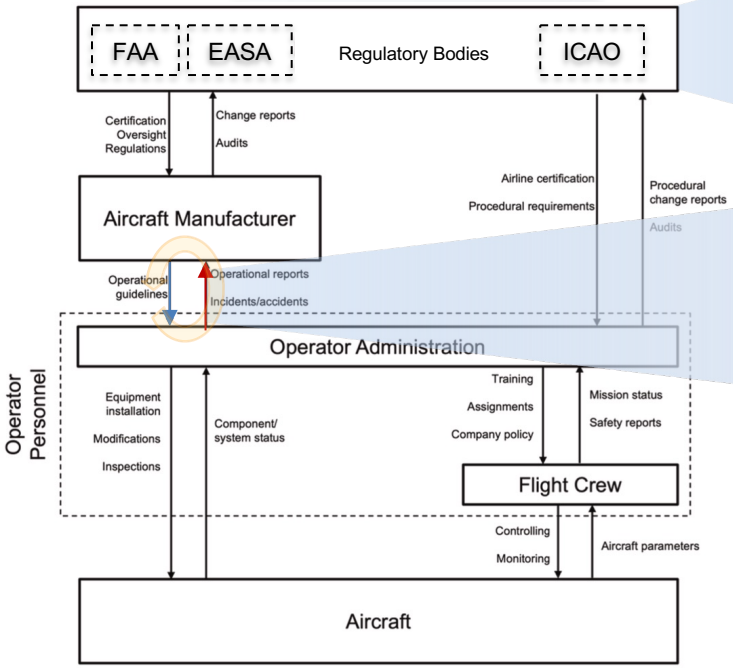
CAST Analysis



Certification decision-making

- Decision not to certify the S92A for elevated helideck operations when **70% of all S92A are operating in this market**
- Decision to include, and later to **remove language in S92A certification** that it cannot be operated from an elevated helideck or helipad
- ***Recommendation 2:*** Utilize CAST within the regulatory authority itself to identify more detailed causal factors contributing to unsafe decision-making
- ***Recommendation 3:*** *Further incorporate systems-theoretic analyses during the process of making and assessing regulatory and certification decisions*

CAST Analysis



"Limited Exposure"

- Short period where helicopter **cannot safely continue** flight after engine failure
- Example: S92A helideck operations

"No Exposure"

- Helicopter can **safely continue flight at all times**, even after engine failure
- Example: S92A other operations

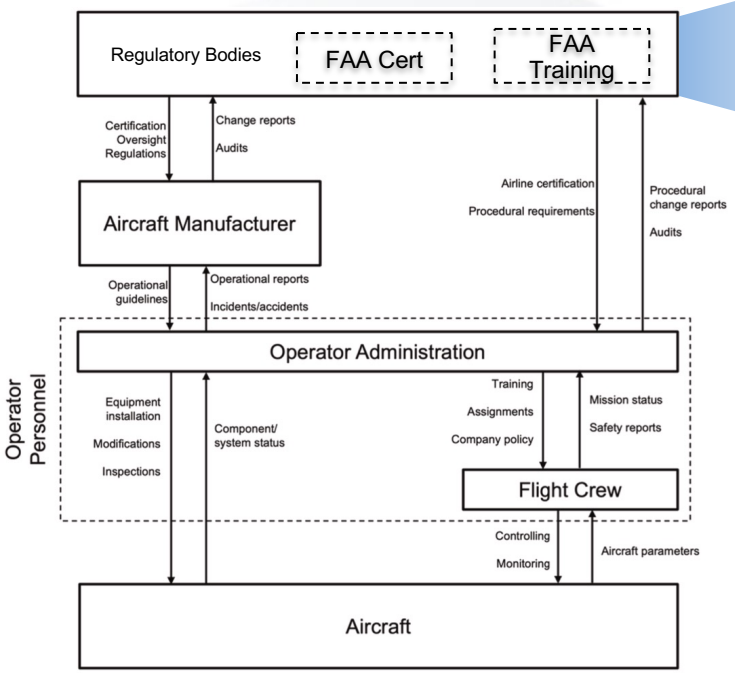
ICAO and EASA: Limited exposure is **hazardous or catastrophic**

S92A RFM: A **"safe forced landing"** is the worst-case scenario in the "limited exposure" procedure

- Does not accurately represent a potentially catastrophic crash over helideck or into water

Recommendation 4: *Further standardize communication and improve coordination across regulatory agencies when dealing with regulation that differs across different airspace systems*

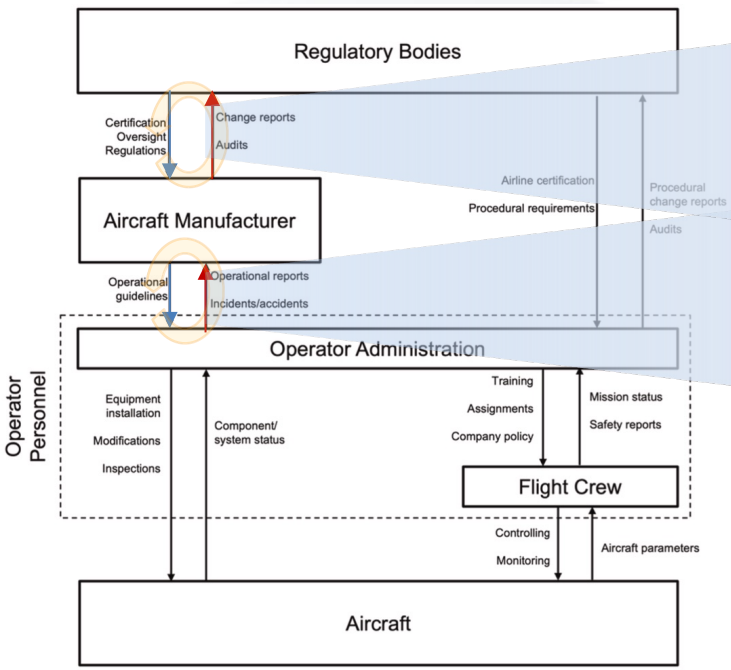
CAST Analysis



- **No requirement** in the S92A FSB Report that offshore air operators flying in USA receive training in Category A elevated helideck takeoff/landing with **powerplant failure before/after CDP/LDP** in flight simulators.
- In their exemptions to operators, FAA often requires that operators' training programs include appropriate training on the profiles associated with "limited exposure", but since FSB report does not include those same requirements, operators are left with **little guidance**
- FAA team that establishes the exemptions has limited feedback or guidance on how to determine training requirements for the elevated helideck operations they are allowing

- ***Recommendation 5:*** *Establish a system by which teams providing operational exemptions to certification regulations can develop and release detailed training requirements appropriate to those exemptions*

CAST Analysis



Poor Risk Metrics

- **Missing feedback** on the metrics used to conduct quantitative risk analyses
- Published inflight shutdown rate from Sikorsky is 0.6 per 100,000 flight hours, some countries with mature S92A offshore operations present rates that are over **twice as high** as the worldwide published rates
- ***Recommendation 6:*** *Reevaluate the use of lagging indicators and probabilistic risk in regulatory decision-making*
- ***Recommendation 7:*** *Require that quantitative metrics claimed in an aircraft's certification basis be periodically audited in the future, compared to the original estimates, and flagged if it differs significantly*

Conclusions

- A systemic-theoretic assessment of a gap between the certification and operation of Transport Category rotorcraft was presented, with specific focus on the Sikorsky S92A.

- The analysis revealed the flawed mental models on the part of flight crews and operators around the certification status of the S92A, stemming from unintended consequences of decisions made by the OEM and regulatory authorities.

- The framework of directly tracing unsafe control actions to mental model flaws and contextual factors, especially across different levels of the control structure, was found to be particularly helpful for analyzing accidents with complex human decision-making, and could be incorporated in guidance for performing CAST in the future.

Conclusions

