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WHAT REGULATIONS AND EDUCATIONAL PROGRAMMES ARE NEEDED TO ENSURE SAFETY OF DRONES?

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Flight Safety Symposium,
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Heathrow

CREATING TOMORROW

SOME FIGURES (PROXIMALLY)

- Commercial Aviation
  - 21.000 aircraft
  - 34 million departures annually
  - 3.5 billion miles flown annually
  - 92 accidents / 474 fatalities (2015)
- General Aviation (2014)
  - About 365.000 aircraft
  - ? departures
  - 42 million flight hours annually
  - x 50 more accidents than commercial aviation (EASA, FAA)
- Drone market
  - 700.000 - 1.200.000 drones sold worldwide only in 2015
  - ? departures, miles, hours
  - 37 accidents, 584 occurrences only in EU in 2015.

HOW MUCH IS AVIATION REGULATED?

- Commercial aviation:
  - Fully standardized for airworthiness, air operations, staff qualifications, air navigation, aerodromes, airspace control, control & management across all levels (e.g., from pilots to authorities) etc.
- General aviation:
  - Mostly standardized for aircrew qualifications
  - Less strictly regulated for airworthiness, air navigation, aerodromes, control & management
- Drone flights regulations:
  - Focus mainly on the end user, who is frequently the only responsible for a safe flight.
  - Lack of reference to the role and responsibilities of the manufacturers and authorities.
  - No universally accepted risk assessment framework.

2.8 / million dep

140 / million dep

??? / million dep

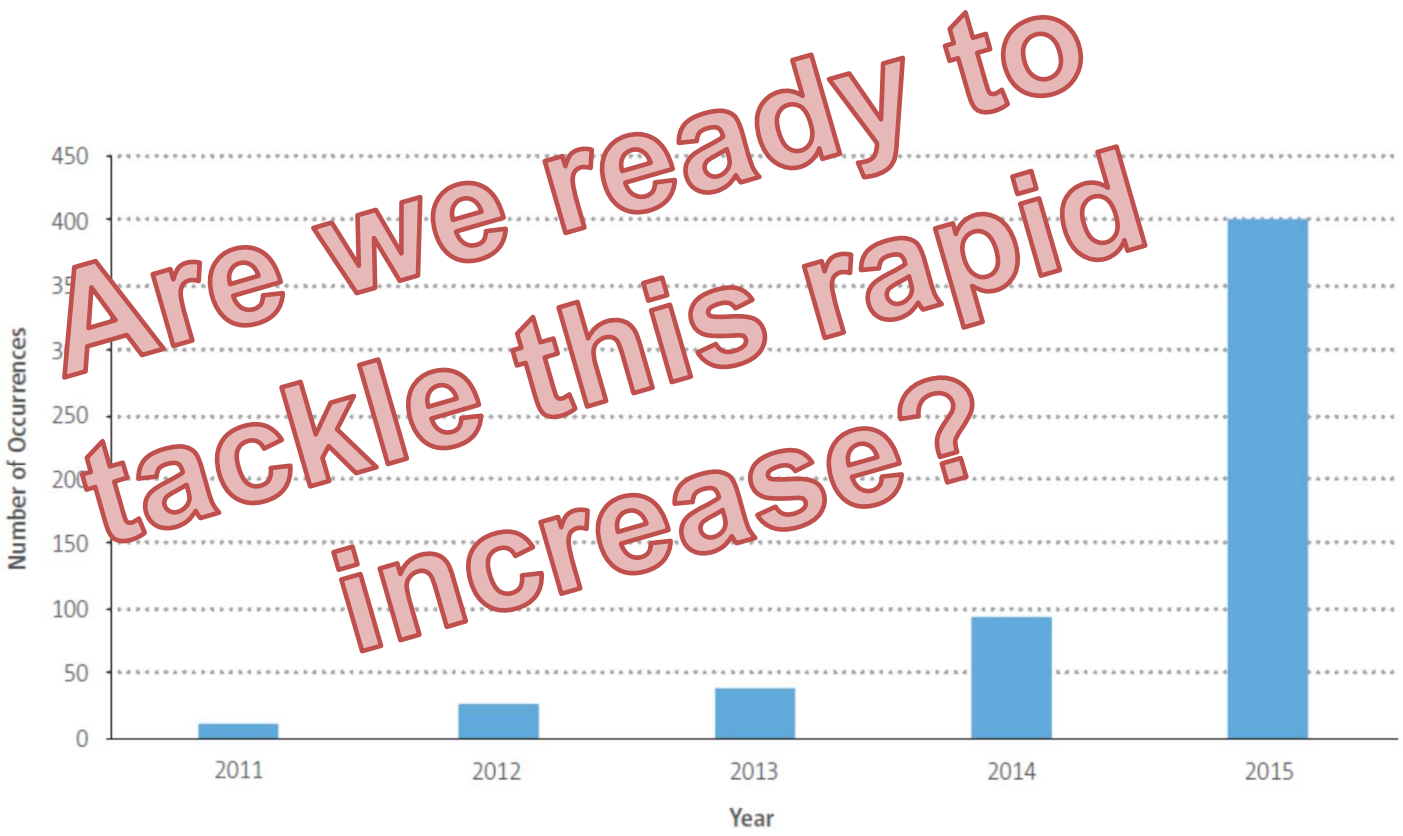
THE CHALLENGES AT THE TECHNICAL LEVEL

- Published hazard analysis and risk assessment methods about drones are based on probabilistic and deterministic approaches.
- However:
  - We do not have data for failures, and such data is (almost) impossible to collect (who, when, how….?)
  - Our assumptions of “pilot” reliability are (almost) invalid:
    - Drone users is a totally heterogeneous and uncontrolled population with the role of both maintaining and flying a drone.
    - The main scope of drone flight is entertainment; no connection of the end-user with social responsibility, job security etc.
    - Drone users lack knowledge, experience and training in human performance limitations (not only regarding aviation…).
    - Drone users lack detailed technical knowledge of how drones function, so to react successfully to events not listed in manuals (assuming that they read the latter…)

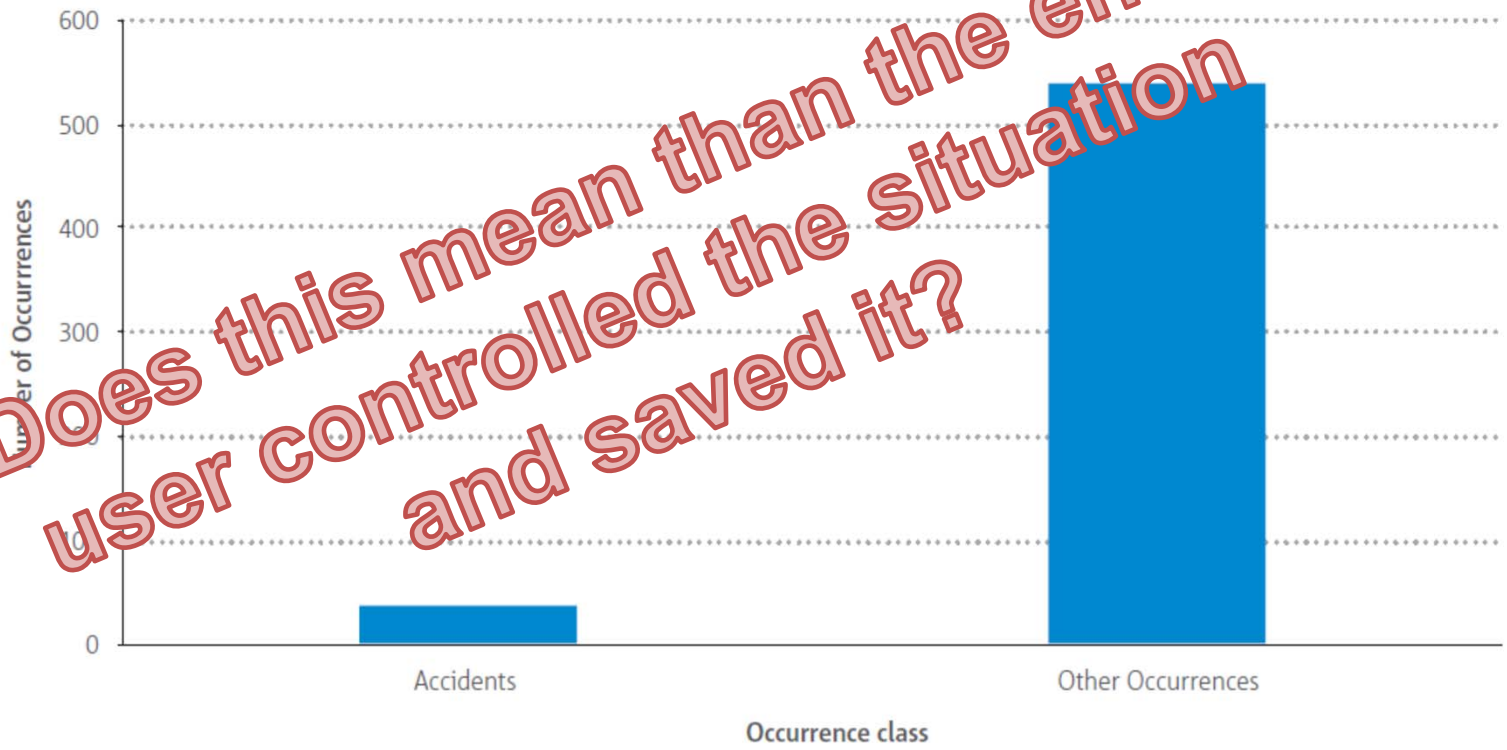
INFORMATION IN ONE PLACE

TYPE	REGULATED	FLEET	FAILURE DATA	ACCIDENT RATE
COMMERCIAL AVIATION	STRICTLY	21.000	PLENTY	0.28 / mil. dep.
GENERAL AVIATION	MOSTLY	365.000	A LOT	104 / mil. dep.
DRONE OPERATIONS	LOOSELY	UNKNOWN (700.000 – 1.200.000 sold annually)	OCCASIONAL	???

DRONE EU OCCURRENCES 2011-2015

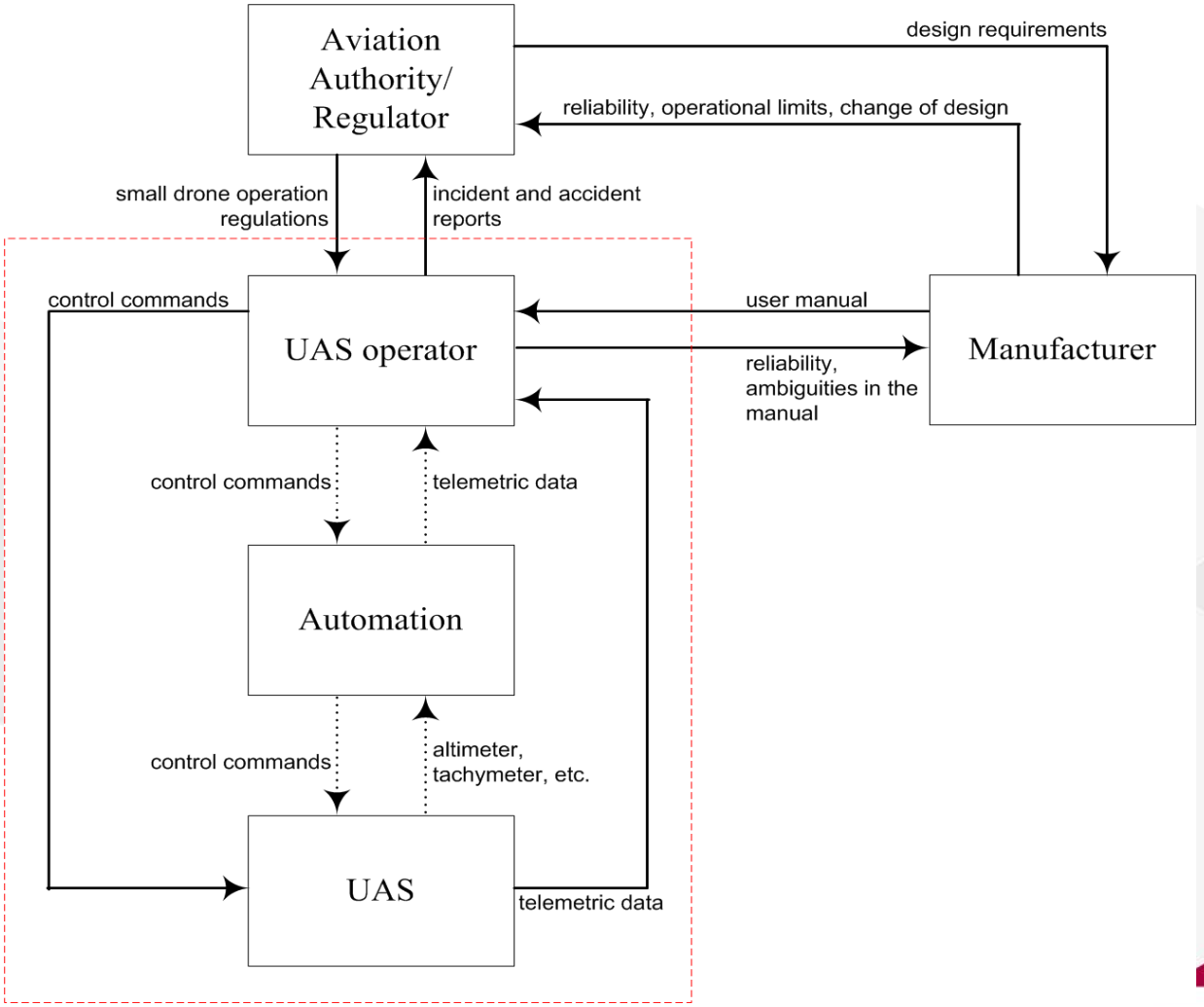


DRONES EU OCCURRENCE CLASSES 2011-2015



Does this mean than the end-user controlled the situation and saved it?

A SYSTEMIC VIEW



RESEARCH METHOD

- Application of the System Theoretic Process Analysis (STPA) method (Leveson, 2011) on a small drone system.
- Generation of:
  - 28 hazardous states
  - 24 causal factors
  - 67 safety requirements across: authority, manufacturer, end-user and automation.
  - Assignment of type of responsibility for each requirement/actor: Regulate, Document, Define, Act, Informed, Support
- Gap analysis and statistical comparison amongst:
  - Specifications of 19 highly marketed drones with available manuals online.
  - Content of regulatory frameworks from 56 countries.

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RESULTS: DRONES' ANALYSIS

DRONE MODEL	RATE OF REQUIREMENTS MET PER CONTROLLER		
	MANUFACTURER	END-USER	AUTOMATION
1	0.545	0.383	0.362
2	0.727	0.553	0.638
3	0.727	0.596	0.638
4	0.652	0.563	0.489
5	0.455	0.383	0.362
6	0.606	0.511	0.511
7	0.455	0.383	0.319
8	0.636	0.489	0.426
9	0.515	0.404	0.277
10	0.318	0.191	0.404
11	0.303	0.234	0.128
12	0.606	0.617	0.255
13	0.364	0.319	0.277
14	0.773	0.660	0.681
15	0.561	0.447	0.426
16	0.576	0.511	0.319
17	0.515	0.447	0.383
18	0.712	0.660	0.447
19	0.652	0.574	0.426

RESULTS: DRONE'S COMPARISON

- The drones are similar amongst them as follows:
  - Manufacturer requirements: 0.440
  - End-user requirements: 0.433
  - Automation requirements: 0.433
- The higher the drone price the more the requirements met.

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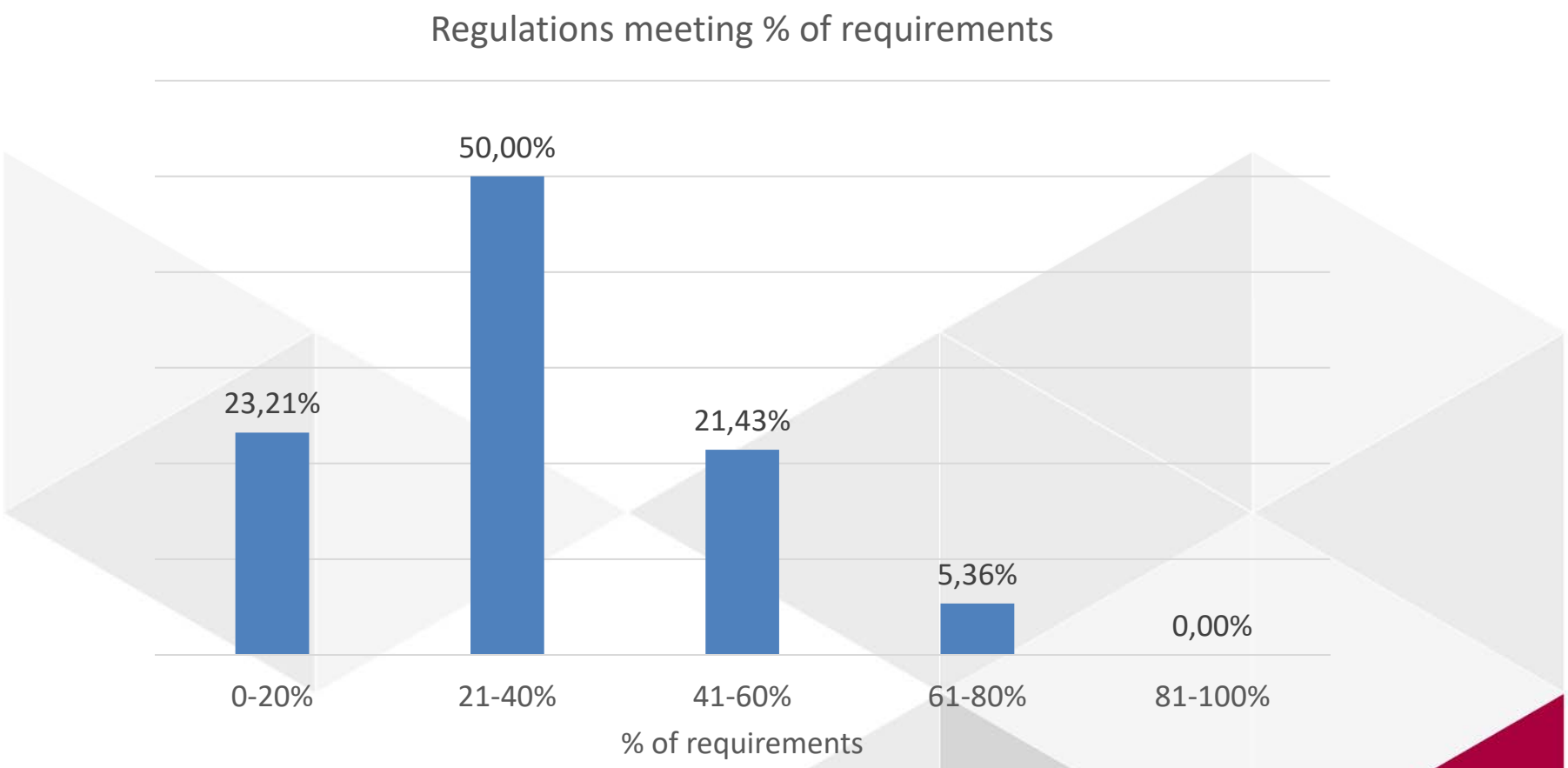
RESULTS: REGULATIONS' ANALYSIS



Minimum value: 5.3%, Maximum value 66.7%

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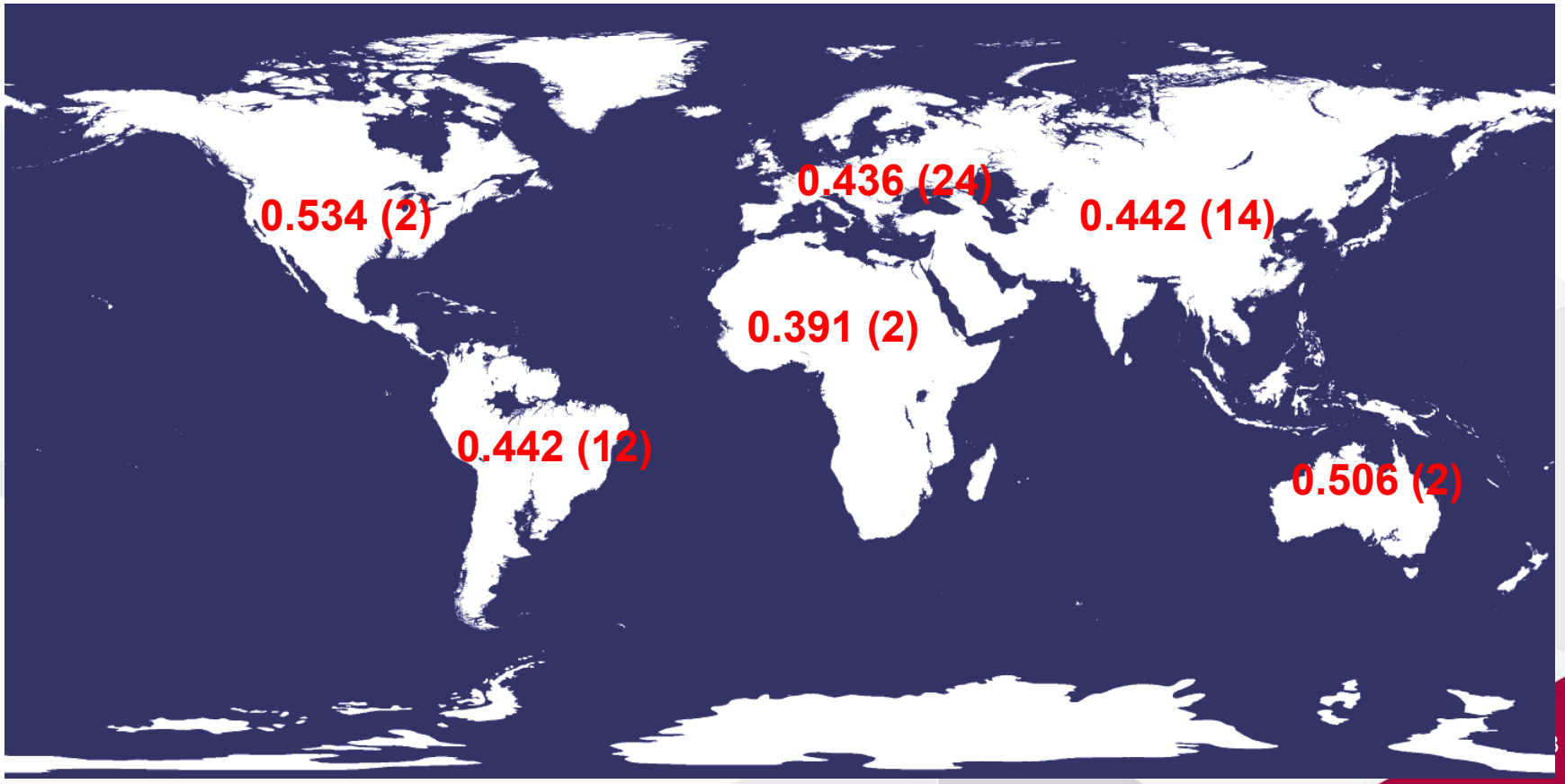
RESULTS: REGULATIONS' COMPARISON



OVERALL AGREEMENT: 0.432

RESULTS: REGULATIONS' COMPARISON

- Things are even "worse" in terms of diversity and complexity:
  - Req: Operator shall maintain continuous visual contact with drone during flight.
    - All 56 authorities dictate so.
    - 33 States have no value for the distance between end-user and drone. Some require extra attention to weather conditions, obstacles, drone capabilities etc.
    - 11 States allow a maximum distance between 100m to 5.5Km. One of those States express the distance in Ft and another in Miles.
  - Highly different requirements about:
    - Skills and competencies of the operator
    - Flight area boundaries
    - Separation from other flying objects

CONCLUSIONS (1/2)

- Safe predictions for the impact of drones on public safety cannot be made. From a deterministic view, safety events with drones are expected to increase exponentially along time.
- Research on drone safety is mainly based on statistical analysis and specific accident scenarios or drone models. However, adequate and reliable data are not yet available.
- In general, drones meet at a low to moderate level the safety requirements generated from the STPA hazard analysis.
- There is high diversity amongst drones regarding the extent to which they meet the safety requirements derived with STPA.

CONCLUSIONS (2/2)

- A common regulatory framework based on a systemic and systematic risk analysis is missing.
- Current regulations assign the end-user almost as the only responsible for observing rules and limits.
- Existing regulations meet the requirements of the authority level at extremely low to moderate levels.
- Regulations across States are highly different amongst them, even when they address the same requirement.
- The high differentiation of rules across countries might confuse users and affect the market.

RECOMMENDATIONS (1/2)

- Engineers need to consider new hazard analysis methods based on systemic approaches. The System Theoretic Process Analysis has been applied widely with success and has more analytical power than traditional reliability and probabilistic methods.
- Human factors must be embedded early in the design of drones and basic concepts of human performance must be taught in the early years of studies.
- Automation needs to support the end-user in meeting the objectives of the flight by maintaining limits. Wireless links of automation with national or regional platforms might allow downloading and uploading such limits.

RECOMMENDATIONS (2/2)

- A common regulatory framework based on systemic and systematic risk analysis is needed to avoid impeding drone market growth.
- Such a framework must clearly state the roles, responsibilities and interdependencies of the main system controllers, namely authorities, manufacturers and end-users.
- States might adopt a customizable and flexible regulatory framework which will:
  - Classify drones depending on how risk control is distributed between the operator and the automated functions of drones.
  - Based on the classification above, define the set and boundary values of certification, training, maintenance etc. requirements

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Questions?

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