UAS CLASSIFICATION

Key to effective airworthiness and operational regulations

Royal Aeronautical Society Unmanned Aircraft Systems Specialist Group
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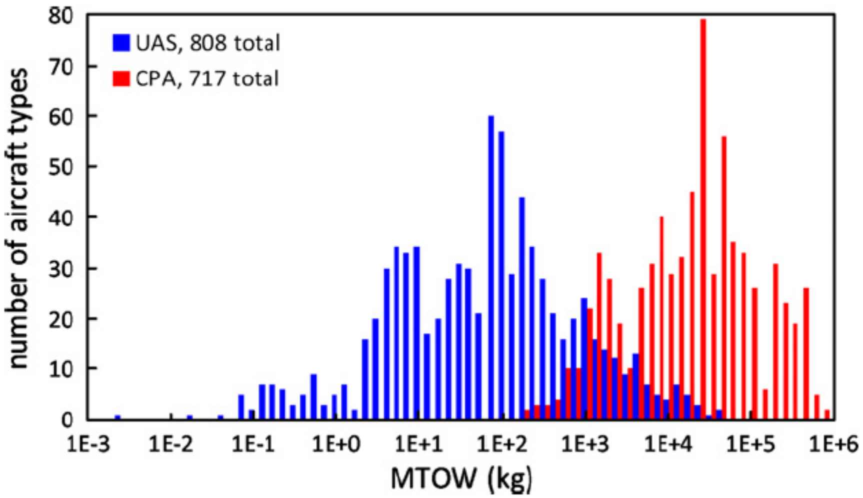
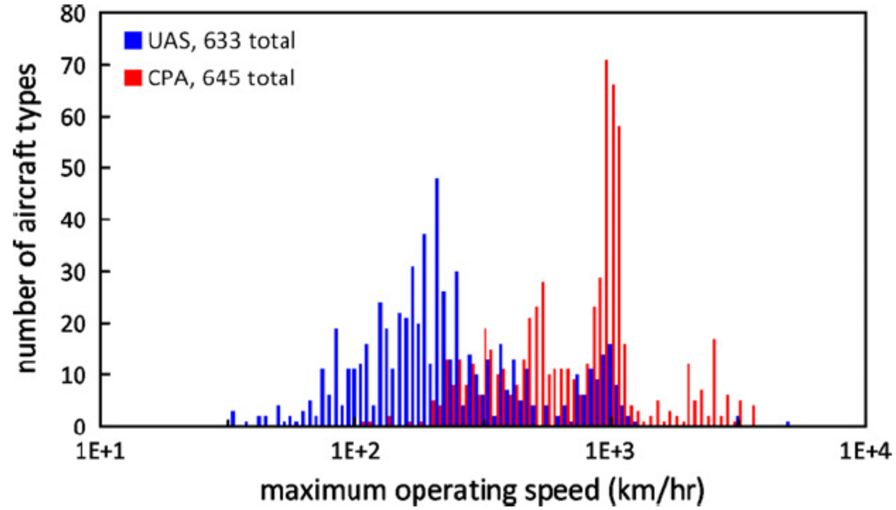
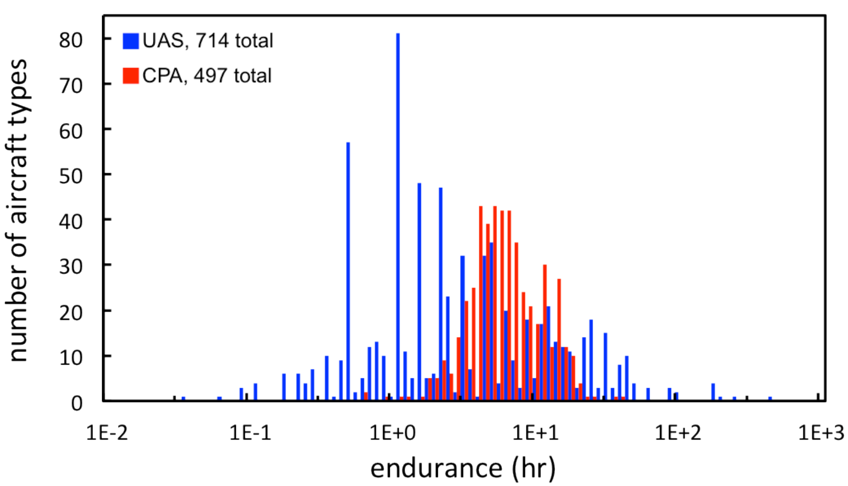
PROBLEM

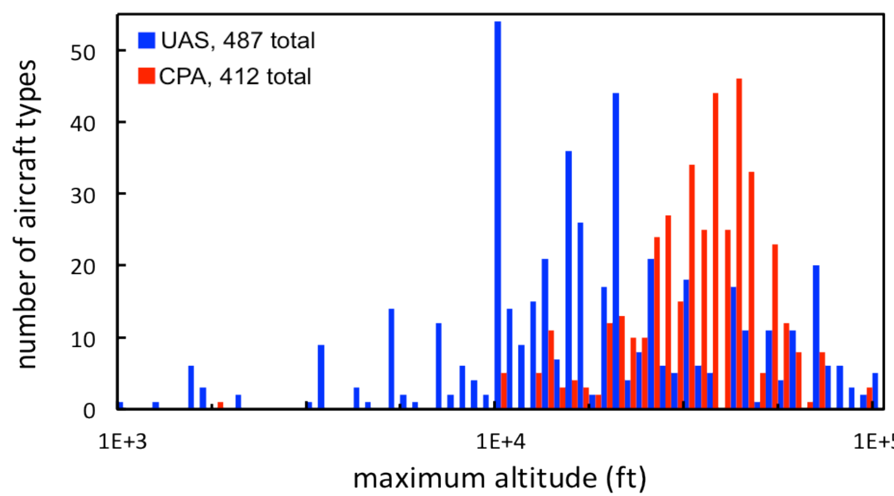
- Classification is at the foundation of an effective framework of regulations for UAS
- Necessary to promulgate regulations "appropriate" to a particular UAS and the nature of its operations
- One size will not fit all
- Conventional aviation categories are not appropriate

WHAT ARE WE TRYING TO CLASSIFY?









UAS data supplied from a database compiled and maintained by the Defence Science and Technology Organisation (DSTO), Australia. CPA data obtained from Aviation Week and Space Report and Jane's All the World's Aircraft. Reference [1].

CLASSIFICATION – GUIDING PRINCIPLES

- The classification system should be (Refs. [1,2]):
  - Contiguous
    - Provide unambiguous coverage
  - Complete
    - Cover all UAS (no gaps)
  - Sufficient resolution
    - Enough categories to ensure an appropriate tailoring of regulation/ representation of the unique groupings within the fleet
  - Practicable
    - Provide a workable/usable solution for the regulator
  - Justifiable
    - Have a defensible basis on which to warrant the scheme and its costs to industry
  - Transparent
    - All assumptions, data and working should be disclosed
  - Objective
    - be independent of the desires of any one stakeholder

For What Reason?

- Classification for UAS Airworthiness
  - development of type certification categories for tailoring and promulgation of standards and practices relating to the design, manufacture, maintenance and operation of UAS
  - for the management of the risks to the people and property over-flown

- Classification for UAS Operations
  - VFR/IFR? CLASS A, B, C – F Airspace? Relevant to UAS?
  - categories of UAS operations for tailoring and promulgation of equipage and procedures within the airspace system
  - ensure the safety of UAS operations alongside other airspace users and to maintain the efficiency of the airspace system

- Must consider a “system of systems”: the UAS (aircraft, ground, communications, …) and its environment (ATM system, airspace users, weather, areas overflown, …)

Classification for Airworthiness

- Purpose of airworthiness regulations is to manage the risk to people over flown (Chicago Convention 1944)

- Risk is not constrained to the properties of the UAS, must also consider where it is being operated

…with a manned aircraft you have to build to the same standard no matter what is underneath you, but among unmanned aircraft, acceptable safety for flights exclusively over oceans can be achieved with rather more rickety machines than would be fit to fly over a city. [3]

- Classification must partition the diversity of UAS operations over inhabited areas into categories for which regulations can then be developed

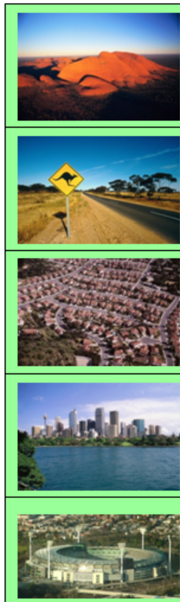
Airworthiness Framework (Part 21 Equivalent for UAS)

Direction of increasing magnitude of potential loss

Type Category of UAS

Direction of increasing potential for realising loss

Category of Operational Environment



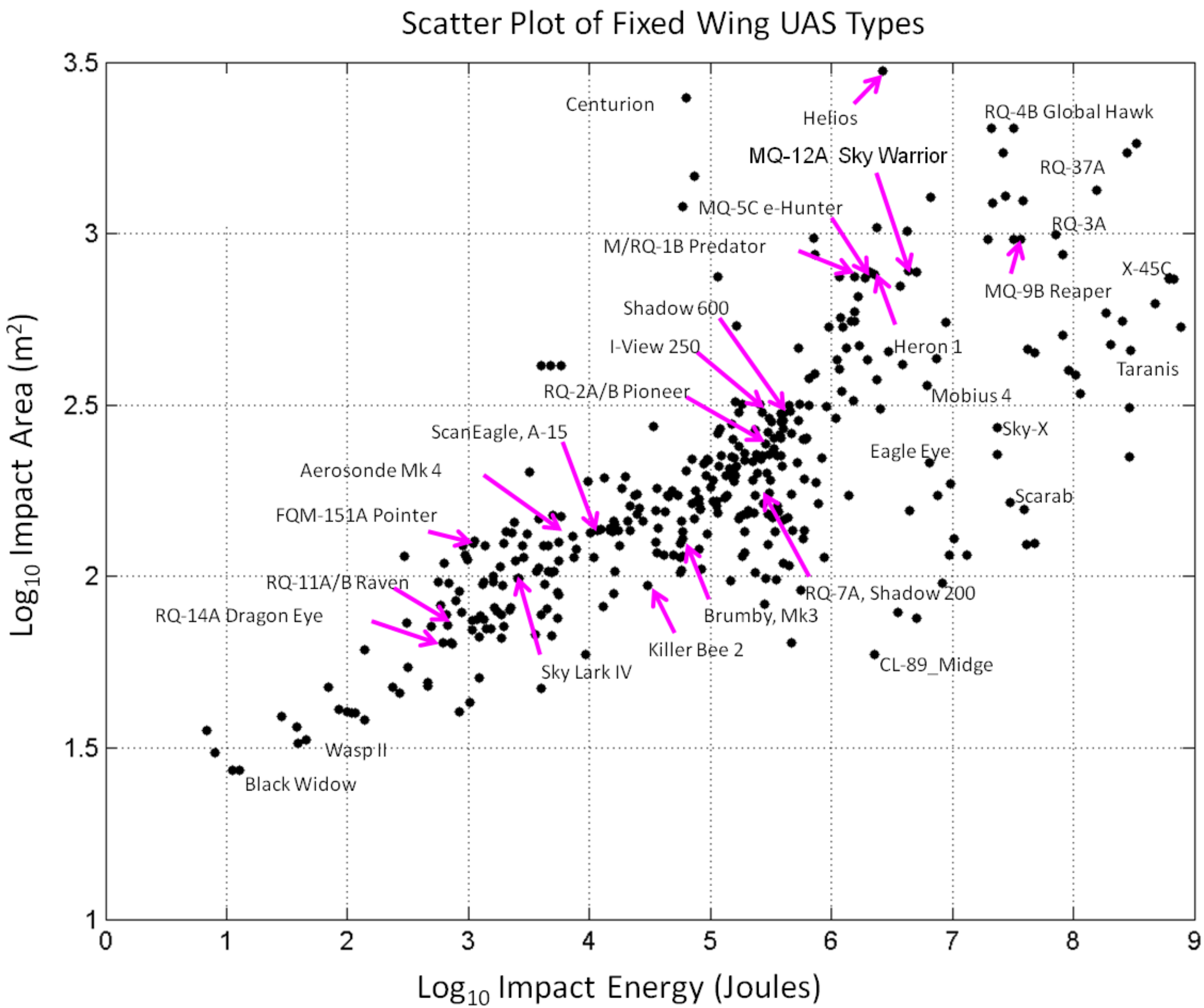
	Type I	Type II	Type III	Type IV	Type *n*
Cat I	Cert 1	Cert 1	Cert 1	Cert 1	Cert 1
Cat II	Cert 1	[illegible]	Cert 2	Cert 3	Cert 4
Cat III	Cert 2	Cert 3	[illegible]	Cert 4	Cert 5
Cat IV	Cert 3	Cert 4	Cert 4	Cert 5	Cert ***r***
Cat *m*	Cert 4	Cert 5	Cert ***r***	Cert ***r***	Cert ***r***

Direction of Increasing Risk

Classification For Airworthiness

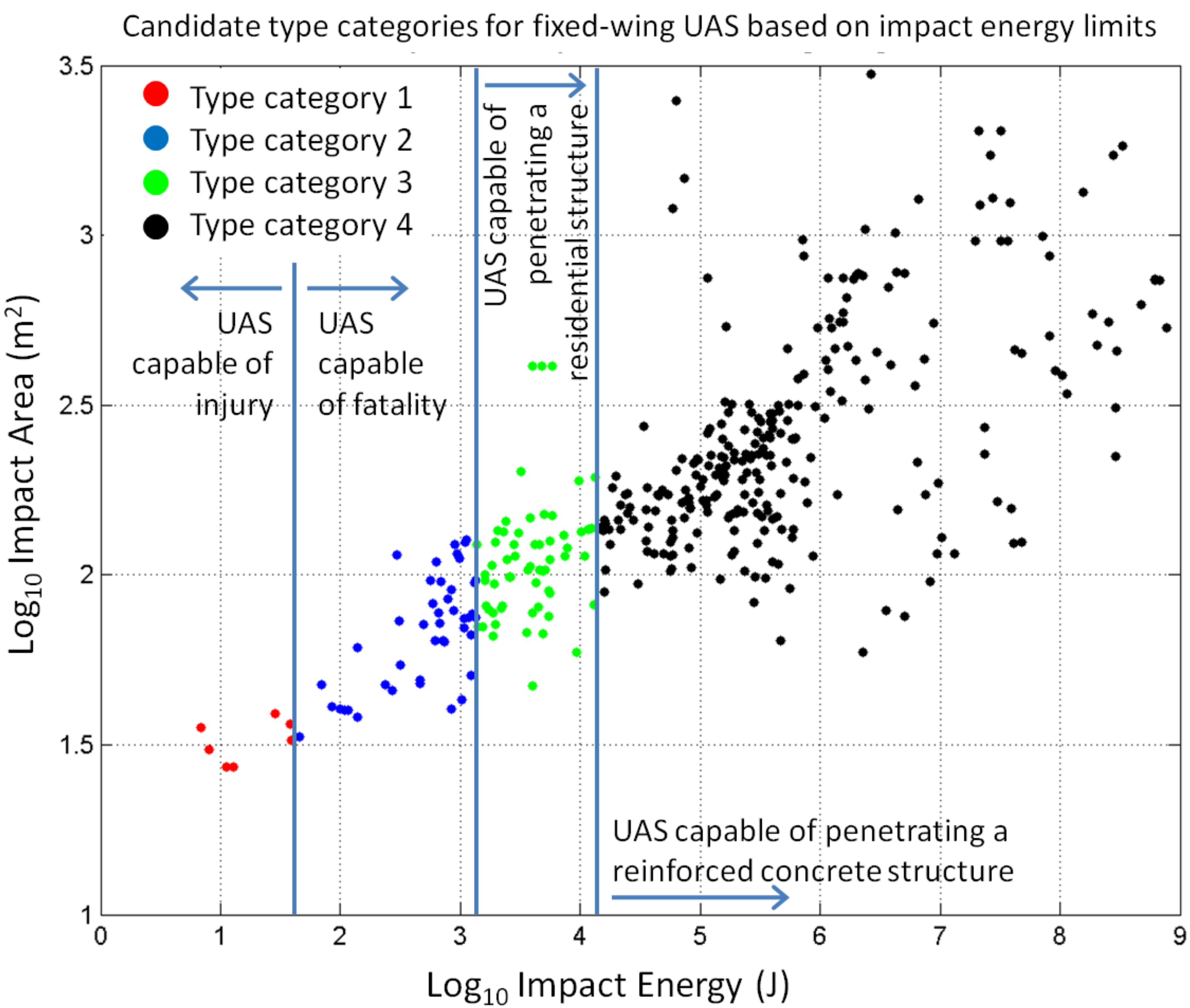
- Type Category (the columns) - Classification of UAS based on the potential harm they can cause
  - defined independent of where they are flown
- Operational Environments (the rows) - Classification of the areas overflown based on their susceptibility to a UAS crash
  - defined independent of the type of UAS over-flying the area
- Operational Scenarios (the cells) – Combination of a particular *UAS Type* with a particular *Operational Environment* defines a unique *Operational Scenario* for which the risks can then be determined
- Airworthiness Categories (the colouring of the cells) – Operational Scenarios (cells) of a similar level of risk are assigned to the same "airworthiness certification category" for which regulations can then be developed in line with the risk.
- Detailed discussion of the framework, its advantages and disadvantages, is provided in REFS [2, 4]

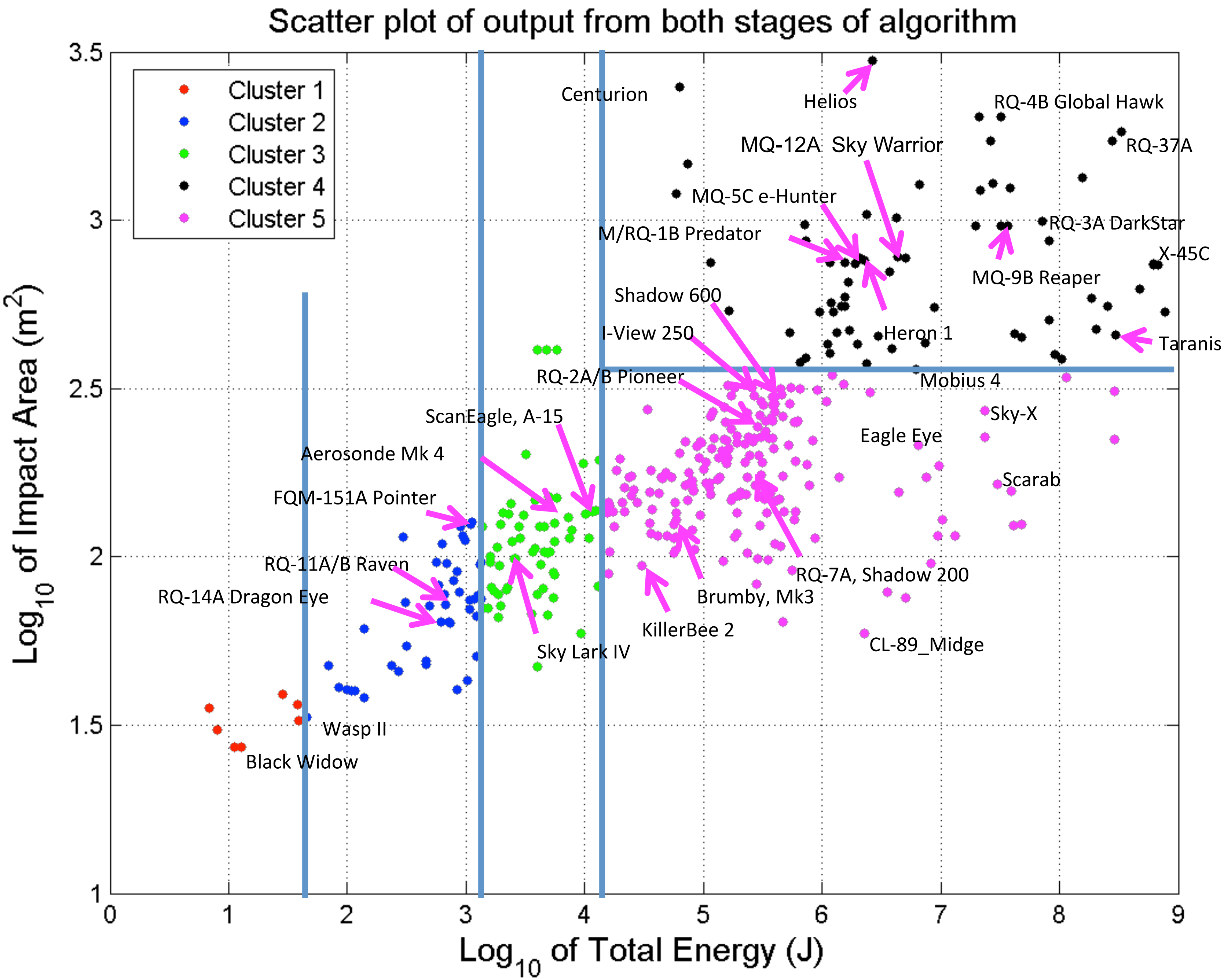
RESULTS

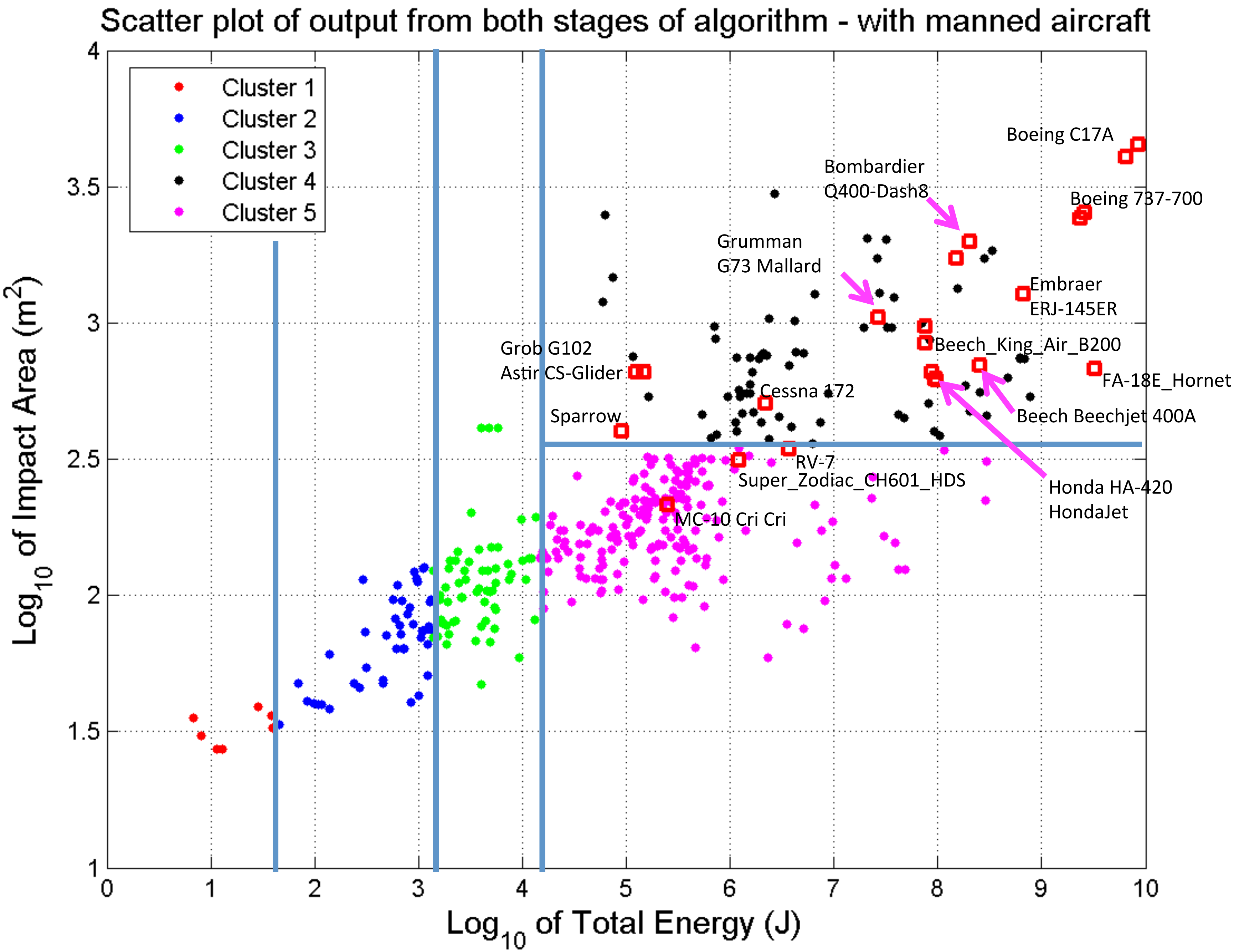


Scatter Plot of Fixed Wing UAS Types
Log10 Impact Area (m2)
Log10 Impact Energy (Joules)
3.5
3
2.5
2
1.5
1
0
1
2
3
4
5
6
7
8
9
Centurion
Helios
RQ-4B Global Hawk
MQ-12A Sky Warrior
RQ-37A
MQ-5C e-Hunter
RQ-3A
M/RQ-1B Predator
X-45C
MQ-9B Reaper
Shadow 600
Heron 1
I-View 250
Taranis
RQ-2A/B Pioneer
Mobius 4
ScanEagle, A-15
Sky-X
Eagle Eye
Aerosonde Mk 4
Scarab
FQM-151A Pointer
RQ-11A/B Raven
RQ-7A, Shadow 200
RQ-14A Dragon Eye
Brumby, Mk3
Killer Bee 2
Sky Lark IV
CL-89_Midge
Wasp II
Black Widow

RESULTS – INDIVIDUAL RISK




Scatter plot of output from both stages of algorithm
Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cluster 5
Centurion
Helios
RQ-4B Global Hawk
MQ-12A Sky Warrior
RQ-37A
MQ-5C e-Hunter
M/RQ-1B Predator
RQ-3A DarkStar
X-45C
MQ-9B Reaper
Shadow 600
I-View 250
Heron 1
Taranis
RQ-2A/B Pioneer
Mobius 4
Sky-X
ScanEagle, A-15
Eagle Eye
Aerosonde Mk 4
Scarab
FQM-151A Pointer
RQ-11A/B Raven
RQ-7A, Shadow 200
RQ-14A Dragon Eye
Brumby, Mk3
KillerBee 2
Sky Lark IV
CL-89_Midge
Wasp II
Black Widow
Log10 of Impact Area (m2)
Log10 of Total Energy (J)


Scatter plot of output from both stages of algorithm - with manned aircraft
Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cluster 5
Boeing C17A
Bombardier
Q400-Dash8
Boeing 737-700
Grumman
G73 Mallard
Embraer
ERJ-145ER
Beech_King_Air_B200
Grob G102
Astir CS-Glider
FA-18E_Hornet
Cessna 172
Sparrow
Beech Beechjet 400A
RV-7
Super_Zodiac_CH601_HDS
Honda HA-420
HondaJet
MC-10 Cri Cri
Log10 of Impact Area (m2)
Log10 of Total Energy (J)

Final Type Classification

Type Category	Boundary Conditions	Example UAS
1	$KE_{max} < 42$ J	Black Widow, Hornet
2	42 J $\leq KE_{max} <$ 1,356 J	Pointer, Raven
3	1,356 J $\leq KE_{max} <$ 13,560 J	ScanEagle, Aerosonde Mk4
4	13,560 J $\leq KE_{max}$ $I_{area} < 347$ m^2	Shadow 600
5	13,560 J $\leq KE_{max}$ 347 m$^2 \leq I_{area}$	Heron 1, Taranis, Global Hawk

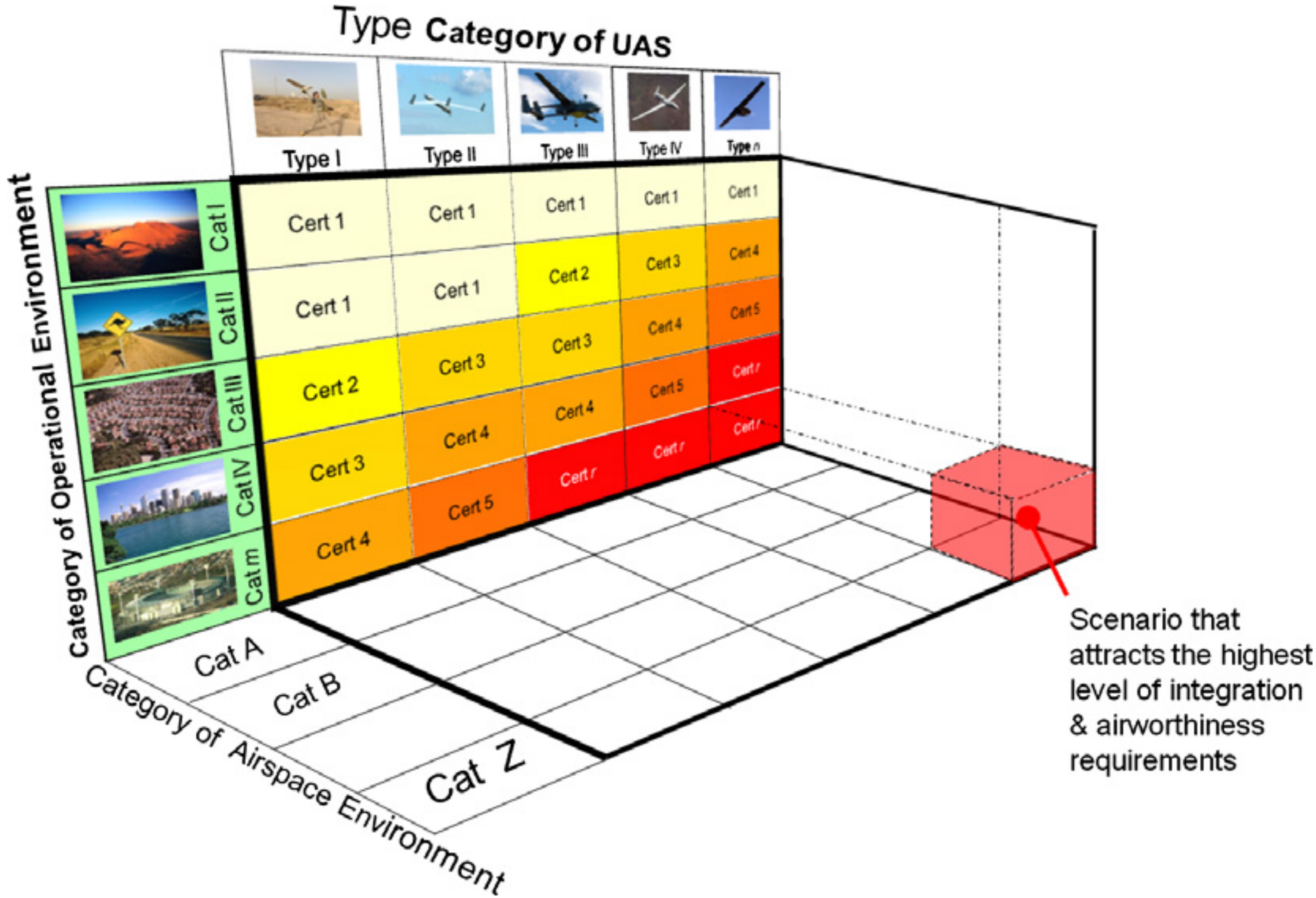
SUMMARY OF AIRWORTHINESS CLASSIFICATION

- Classification of operational environment is subject of future work
- Type classification approach is risk-based
  – Uses a database of current
  – Based on conservative casualty models (higher fidelity modelling could be used)
  – Uses mathematical clustering to ascertain categories where there is no "easy" distinction

Classification For Airspace Operations

- Primary purpose is to develop and promulgate regulations on UAS operations so as to manage the risk to other airspace users due to a midair collision
  - More than just IFR/VFR and Class A-F
  - Must consider all “layers of defence”
  - Distribution, type, task loading and equipage of other airspace users
  - Both sides of the collision equation (see and be seen)
  - Potential for damage to other aircraft (>2kg, FAR 25.631 and FAR 35.36)
  - ATM services provided and requirements
  - Flight planning

Bringing Them Together?



SUMMARY STATEMENTS

- Plethora of existing classification approaches
  - Why haven't they been taken up?
- Key points
  - Identify the regulatory purpose for the classification scheme
  - Stick to the guiding principles
  - Risk cannot be argued with (it's why regulations are developed)
  - Different schemes and approaches may be needed for different operational contexts (*e.g.*, Australia, Canada vs Europe) however, the approach should be common to facilitate a mapping between schemes

References

[1] Clothier, Reece A., Palmer, Jennifer L., Walker, Rodney A., and Fulton, Neale L. (2010) Definition of airworthiness categories for civil Unmanned Aircraft Systems (UAS). In Proceedings of The 27th International Congress of the Aeronautical Sciences, Acropolis Conference Centre, Nice, France. Available for download here.

[2] Clothier, Reece A., Palmer, Jennifer L., Walker, Rodney A., and Fulton, Neale L. (2011) Definition of an airworthiness certification framework for civil unmanned aircraft systems. Safety Science. Vol. 49 (6), July. pp. 871-885. Author's version available for download here.

[3] T. McGeer and J. Vagners. Wide-scale use of long-range miniature Aerosondes over the world's oceans. Insitu Group, Bingen, WA, USA, 1999. Available for download here.

[4] Clothier, Reece A. (2010) Definition of airworthiness categories for civil Unmanned Aircraft Systems (UAS). Conference presentation made at The 27th International Congress of the Aeronautical Sciences, Acropolis Conference Centre, Nice, France. Available for download here.

More Information

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