Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Office of Civil Aviation FOCA
Directorate Affairs and Services
Innovation Management

SORA
Risk Assessment for unmanned airborne Mobility

Markus Farner, Manager Innovation and Advanced Technologies

Workshop Intelligent and Autonomous Technologies in Aeronautics
Winterthur, 12. September 2017

Content

- Development in Switzerland
- Safety in Aviation
- New Approach for new emerging Challenges
  - ❖ Risk based Approach
  - ❖ Change in Culture
  - ❖ Tool for Risk Assessment

History,
24. April 2010

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für
Umwelt, Verkehr, Energie und Kommunikation UVEK
Bundesamt für Zivilluftfahrt BAZL
Abteilung Sicherheit Flugbetrieb

BAZL, CH-3003 Bern

Lettre signature

Ecole Polytechnique Fédérale de Lausanne
(EPFL)
Laboratory of Intelligent Systems (LIS)
Prof. Dario Floreano
Station 11
1015 Lausanne
Ecole

Referenz/Aktenzeichen: 1/42/42-00
UAS-Bewilligung 0001
Unser Zeichen: kr
Sachbearbeiter: Peter Krüger
Tel. +41 31 325 90 92, Fax +41 31 325 80 56, peter.krueger@bazl.admin.ch
Ittigen, 26. April 2010

BEWILLIGUNG

zum Betrieb unbemannter Luftfahrzeuge ausserhalb direktem Sichtbereich

Das Bundesamt für Zivilluftfahrt (BAZL),

auf Grund des Gesuches vom 16. Dezember 2009 (Beilage 1), dem OPS-Konzept vom 1.3.2010 (Beilage 2), den ergänzenden Unterlagen vom 5.4.2010 (Beilage 3) sowie der unterzeichneten „self declaration" (Beilage 4),

gestützt auf Artikel 18 Absatz 1 Buchstabe b sowie Absatz 3 der Verordnung über Luftfahrzeuge besonderer Kategorien (VLK, SR 748.941),

bewilligt der

Ecole Polytechnique Fédérale de Lausanne (EPFL)
Laboratory of Intelligent Systems (LIS)
Prof. Dario Floreano
Station 11
1015 Lausanne

den **Betrieb mehrerer unbemannter Luftfahrzeuge** (Unmanned Aerial Vehicles: UAV) **ausserhalb direktem Sichtbereich** (Beyond Line of Sight: BLOS) im Rahmen der nachstehenden **Auflagen:**

Bundesamt für Zivilluftfahrt
Postadresse: CH-3003 Bern
Standort: Mühlestrasse 2, 3063 Ittigen
Tel. +41 31 325 80 39/40, Fax +41 31 325 80 32
www.bazl.admin.ch
zertifiziert nach ISO 9001

March 2017

Safety Risk in Aviation

Any aircraft is normally not a danger by itself. It is the operation in which the aircraft takes part, which can create a risk.

- Risk for passenge craft

- Risk for peopl ircrafts in case a collision

- Risk for critica

- A crash can be accepta ar

Basics - Safety of an Operation in Aviation

Traditional Safety in manned Aviation

An Operation is sufficiently safe to accept the risk when:

- ✓ The Organisation behind the Operation is approved to accepted standards
- ✓ They use a crew, which is approved to accepted standards
- ✓ They use aircrafts which design, production & maintenance as well as the organisations behind are approved to accepted standards

The Operation is not sufficiently safe and therefore to prohibit

Safety in non-traditional Aviation

1. Operation is **sufficiently safe** to accept the risk.
   - All is approved to accepted standards
   - Within a legal framework which provides sufficient safety

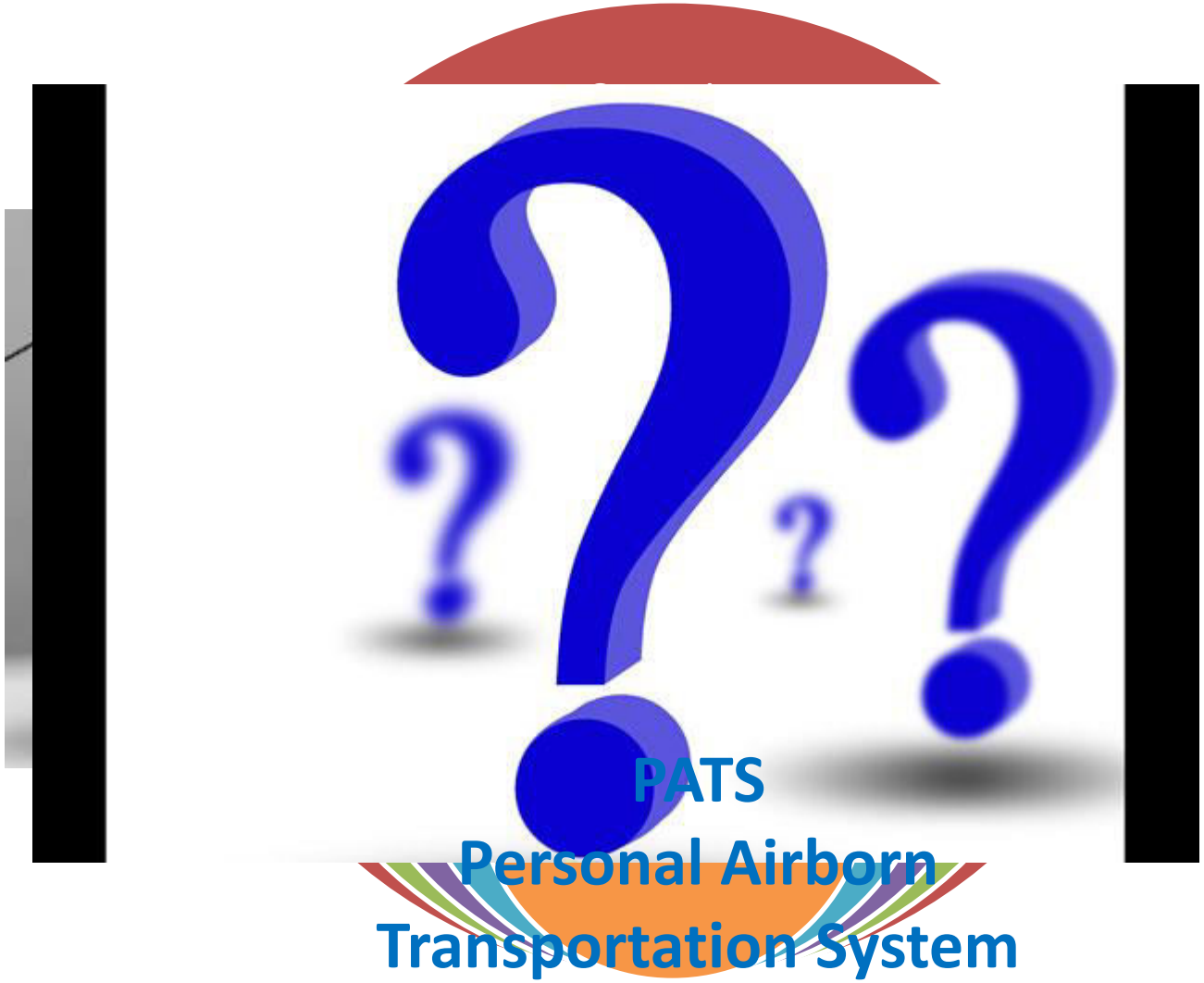
2. Operation is **not sufficiently safe** and therefore to prohibit

3. Operation is **not sufficiently safe** and additional safety barriers are required to accept the risk.

Traditional Risk Assessment

Where we are?

And where we go?



Traditionally open Questions

- Which are the rules to fly? And where to fly?
- What are the rules for the design?
- What about the production?
- Design, Production, Maintenance people? License?
- Certification?
- Certificates?

New Approach

Categories of harm – likelihood estimation

Likelihood of Fatal injuries to third parties on ground	=	Likelihood of having UAS operation out-of-control	X	Likelihood of person struck by the UA if the operation is out of control	X	Likelihood that, if struck, person is killed
Likelihood of Fatal injuries to third parties in the air	=	Likelihood of having UAS operation out-of-control	X	Likelihood of other A/C struck by the UA if the operation is out of control	X	Likelihood that, if struck, the other A/C cannot continue a safe flight and landing
Likelihood of Damage to critical infrastructure	=	Likelihood of having UAS operation out-of-control	X	Likelihood of critical infrastructure struck by the UA if the operation is out of control	X	Likelihood that, if struck, the critical infrastructure is damaged
Likelihood of Fatal injuries to passenger	=	Likelihood of having PATS operation out-of-control	X	Likelihood of a crash of the PATS after operation is out-of-control	X	Likelihood that, if crashed, passenger(s) are killed

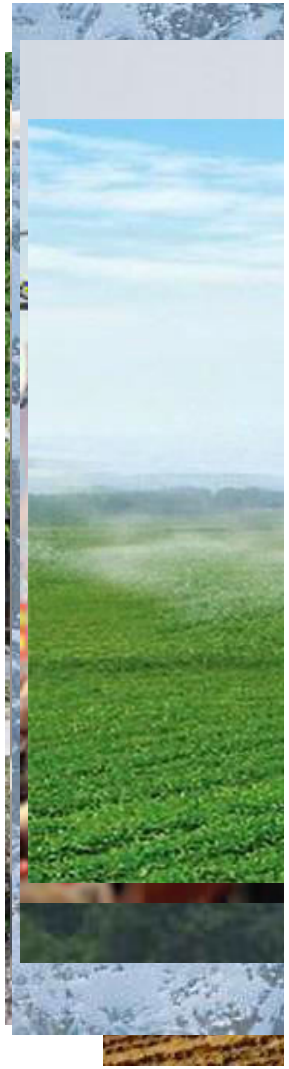
Responsibility?

Who to protect?

- Protection of the people on ground is included in the protection of the people on-board the aircraft.

- Protection of the people on-bord the PATS is included in the protection of 3d parties on ground and in the air.

One size fits all?



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für
Umwelt, Verkehr, Energie und Kommunikation UVEK
Bundesamt für Zivilluftfahrt BAZL

CH-3003 Bern, BAZL

[redacted]

Aktenzeichen: BAZL / 311.34-00043/00012, Projekt 2016/Art.14-2/001 Fly & Film
Ihr Zeichen: Antrag 17.05.2016 Fly & Film SA
Unser Zeichen: fam
Bern, 01.02.2017

BEWILLIGUNG

zum Sprühen von Flüssigkeiten mit einem unbemannten Luftfahrzeug über 30kg Gewicht innerhalb des direkten Augenkontaktes

Das Bundesamt für Zivilluftfahrt (BAZL)

Auf Grund des ursprünglichen Gesuchs vom 17.Mai 2016, und dem eingereichten Operations- und Sicherheitskonzept (**GALLO**) referenziert in Abschnitt 5(a);

Im Einvernehmen mit (E-Mails im Anhang):

- dem Bundesamt für Umwelt (BAFU)
- dem Bundesamt für Lebensmittelsicherheit und Veterinärwesen (BLV)
- dem Staatssekretariat für Wirtschaft (SECO)

gestützt auf:

- Artikel 14a Absatz 2 Buchstabe a der Verordnung über Luftfahrzeuge besonderer Kategorien (VLK; SR 748.941)
- Artikel 9 Absatz 1 der Verordnung über die Verkehrsregeln für Luftfahrzeuge (VRV-L; SR 748.121.11)
- Artikel 4 Absatz b der Verordnung zur Reduktion von Risiken beim Umgang mit bestimmten besonders gefährlichen Stoffen, Zubereitungen und Gegenständen (Chemikalien-Risikoreduktions-Verordnung, ChemRRV; SR 814.81)

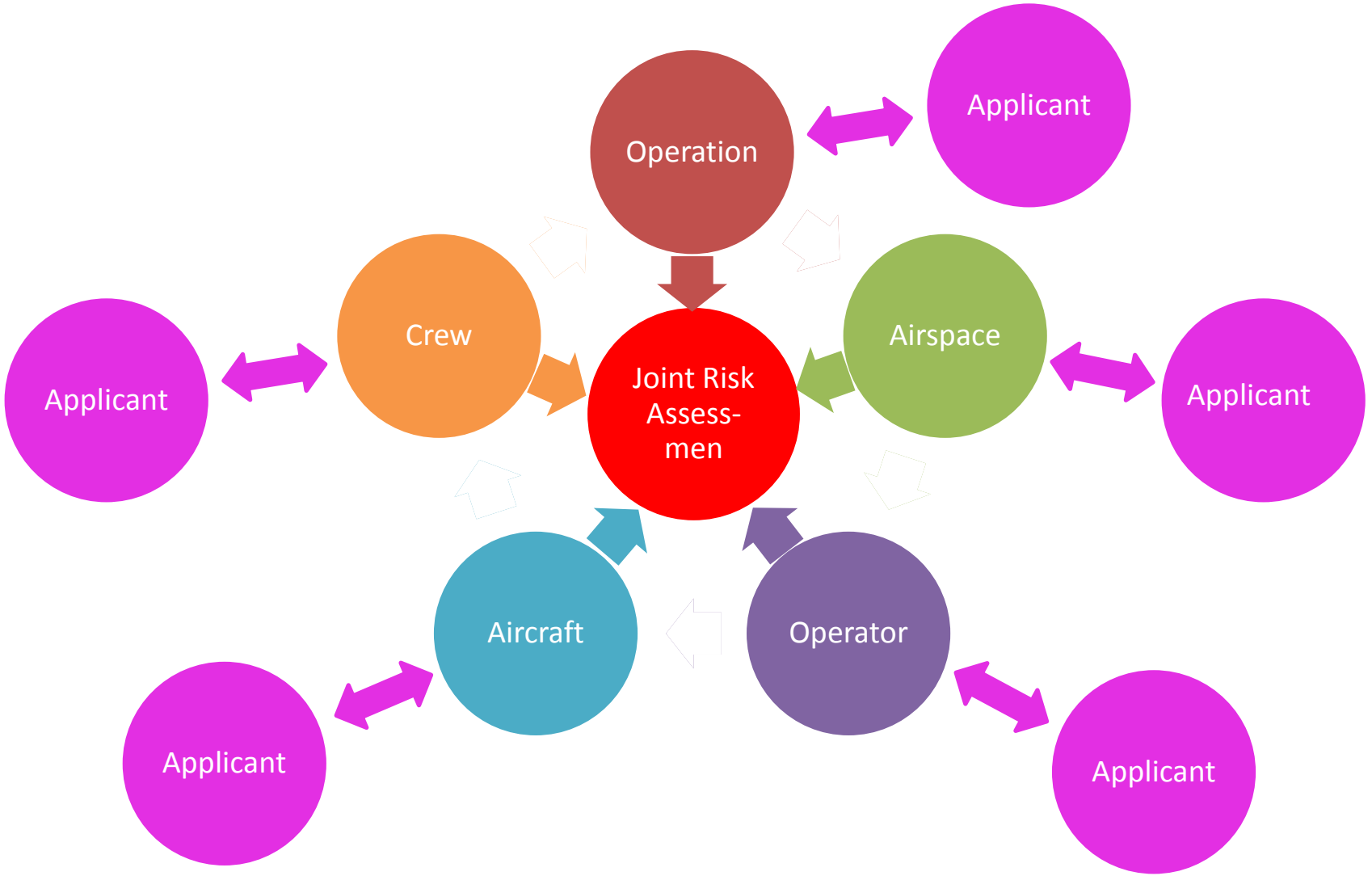
Bundesamt für Zivilluftfahrt BAZL

Postadresse: 3003 Bern
Standort: ,
Tel. , Fax +41 58 465 80 32

www.bazl.admin.ch

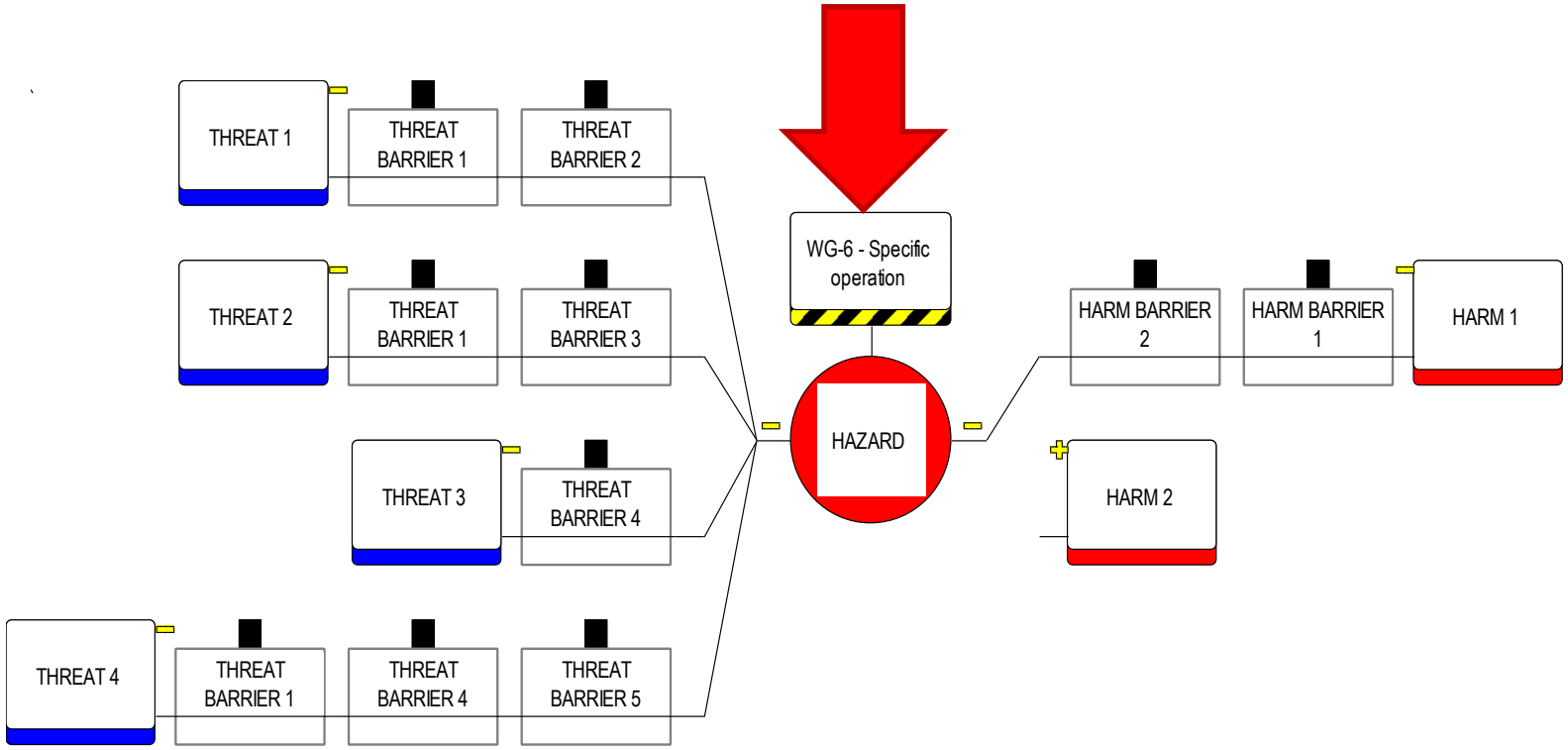
COO.2207.111.3.2518885

Individual Risk Assessment
Joint Risk Assessment



Holistic Risk Model (HRM)

UAS Operation out of Control



10^{-6}	=	Likelihood of having UAS operation out-of-control	X	Likelihood of person struck by the UAS	X	Likelihood that, if struck, person is killed

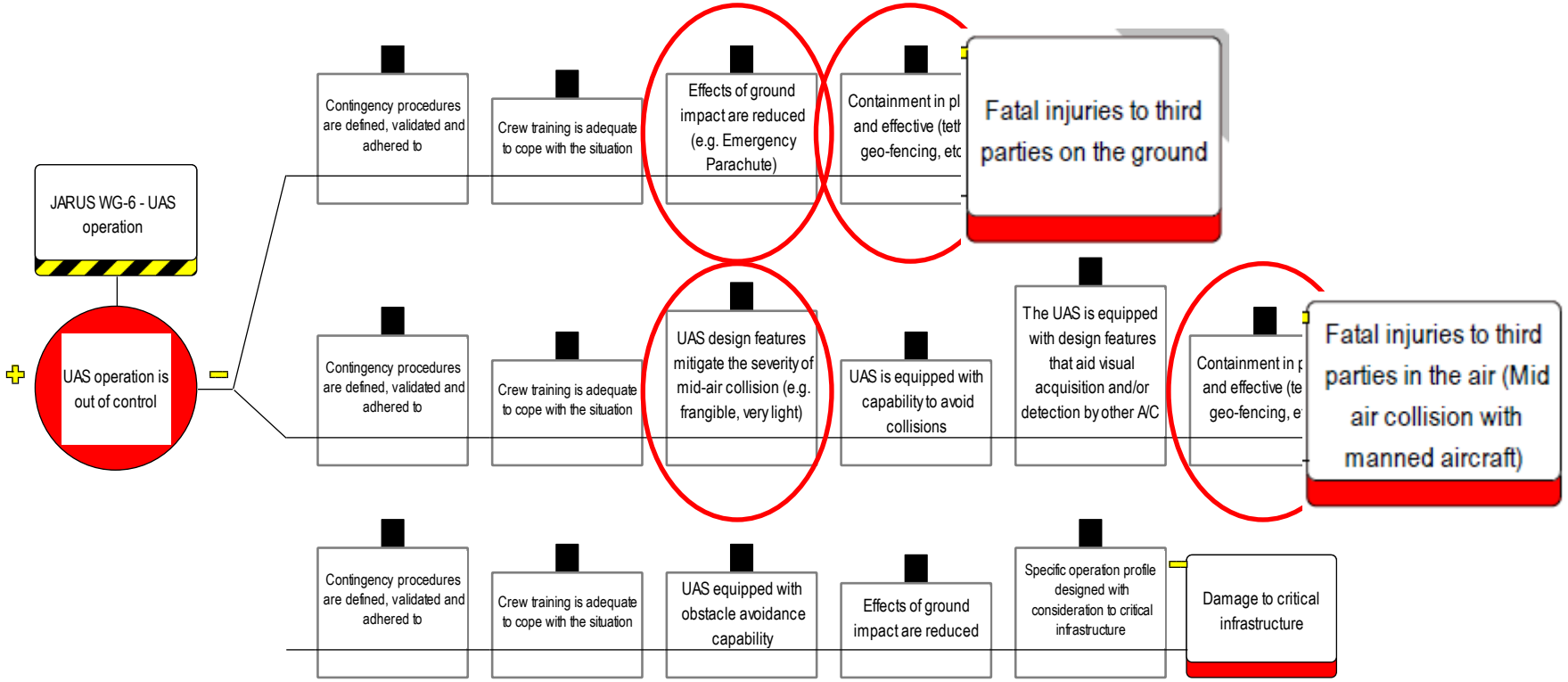
Harm Barriers Principles

Reduce the likelihood of fatalities or injuries

– Reduce the effects of the impact

– Reduction of the number of persons exposed to the risk

Harm & Harm Barriers



Ground Risk Assessment

Intrinsic UAS Ground Risk Class				
Max UAS characteristics dimension	1 m / approx. 3ft	3 m / approx. 10ft	8 m / approx. 25ft	>8 m / approx. 25ft
Typical kinetic energy expected	*< 700 J (approx. 529 Ft Lb)*	*< 34 KJ (approx. 25000 Ft Lb)*	*< 1084 KJ (approx. 800000 Ft Lb)*	*> 1084 KJ (approx. 800000 Ft Lb)*
Operational scenarios				
VLOS over controlled area, located inside a sparsely populated environment	1	2	3	5
BVLOS over sparsely populated environment (over-flown areas uniformly inhabited)	2	3	4	6
VLOS over controlled area, located inside a populated environment	3	4	6	8
VLOS over populated environment	4	5	7	9
BVLOS over controlled area, located inside a populated environment	5	6	8	10
BVLOS over populated environment	6	7	9	11
VLOS over gathering of people	7			
BVLOS over gathering of people	8			

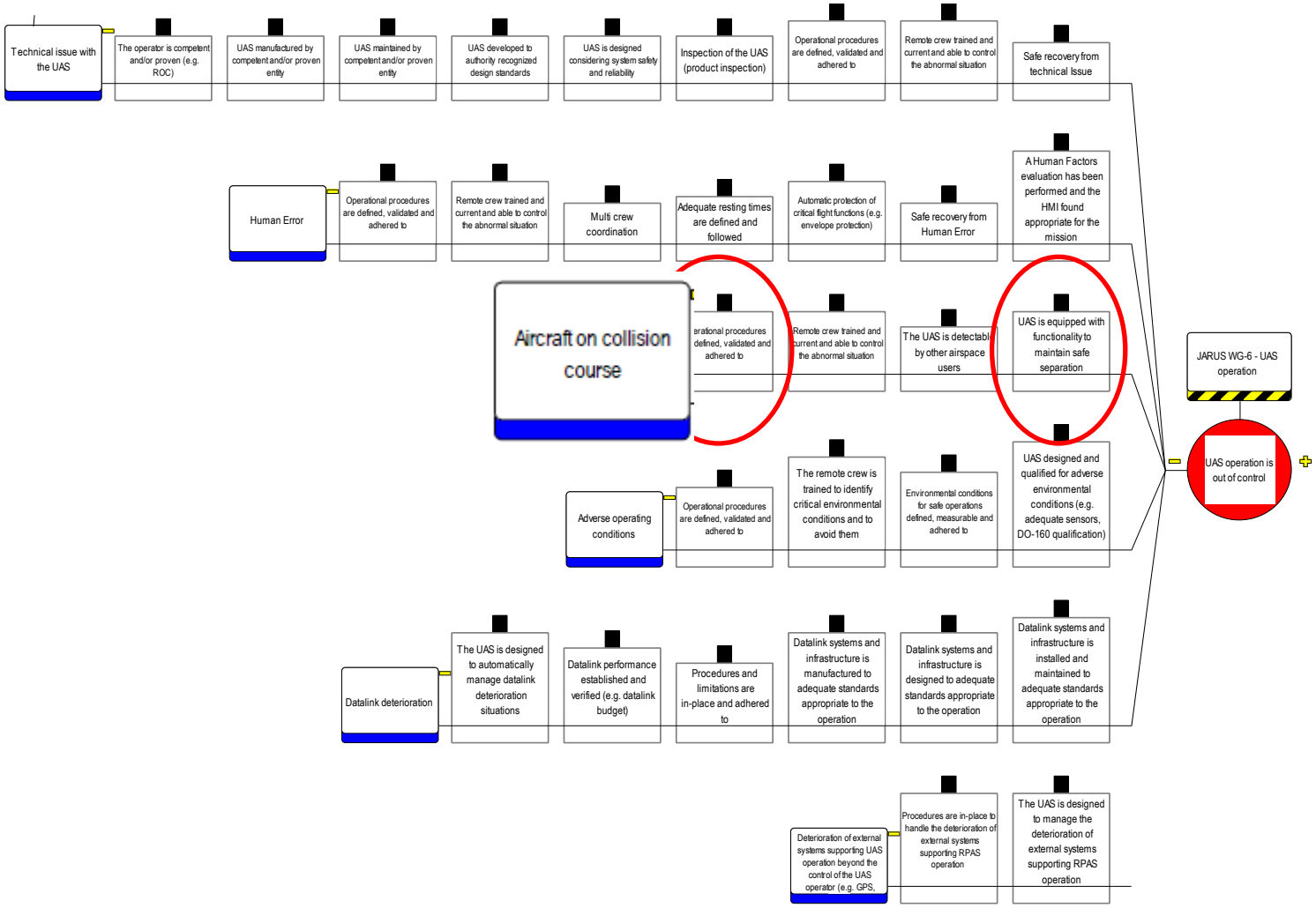
Harm barriers out of SORA

	Robustness		
Harm barriers for GRC adaptation	Low/None	Medium	High
An Emergency Response Plan (ERP) is in place, operator validated and effective	**1**	**0**	**-1**
Effects of ground impact are reduced[d] (e.g. emergency parachute, shelter)	**0**	**-1**	**-2**
Technical containment in place and effective[e] (e.g. tether)	**0**	**-2**	**-4**

Specific Assurance and Integrity Levels (SAIL)

SAIL							
Lethality	UAS Ground Risk Class						
	7	6	5	4	3	2	1
HIGH	VI	VI	V	IV	III	II	I
AVERAGE	VI	V	IV	III	II	I	0
LOW	V	IV	III	II	I	0	0

Threat & Threat Barriers



Threat barriers out of SORA

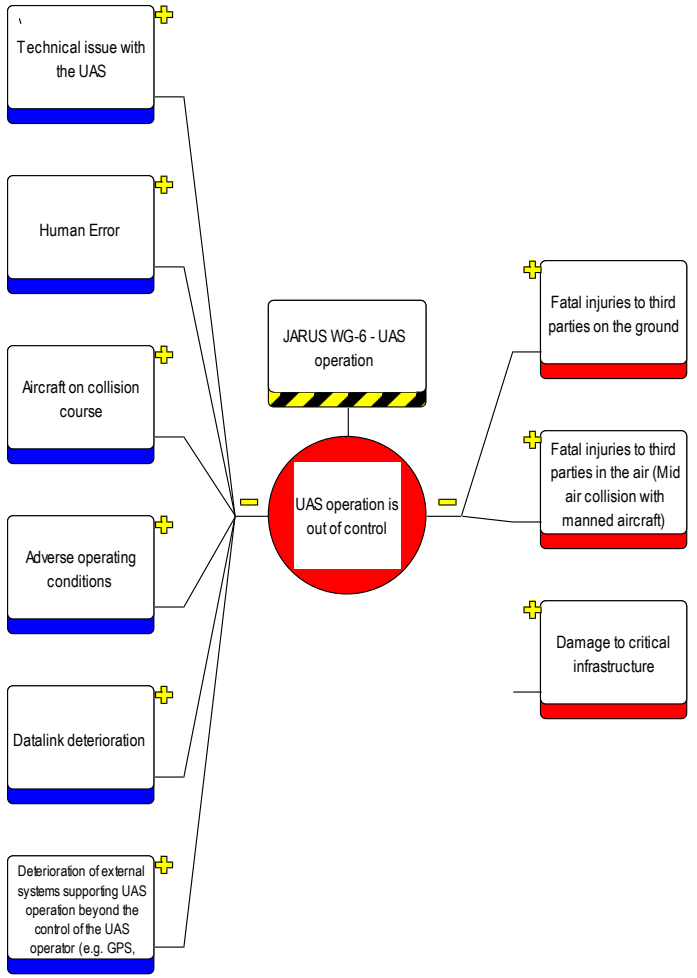
	SAIL					
	I	II	III	IV	V	VI
Technical issue with the UAS						
Ensure the operator is competent and/or proven (e.g. ROC)	O	L	M	H	H	H
UAS manufactured by competent and/or proven entity (e.g. industry standards)	O	O	L	M	H	H
UAS maintained by competent and/or proven entity (e.g. industry standards)	L	L	M	M	H	H
UAS developed to authority recognized design standards (e.g. industry standards)[f]	O	O	O	L	M	H
UAS is designed considering system safety and reliability	O	O	L	M	H	H
Inspection of the UAS (product inspection) to ensure consistency to the ConOps	L	L	M	M	H	H
Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
Remote crew trained and current and able to control the abnormal situation	L	L	M	M	H	H
Safe recovery from technical issue	L	L	M	M	H	H

Holistic Risc Model (HRM)

Level of Robustness

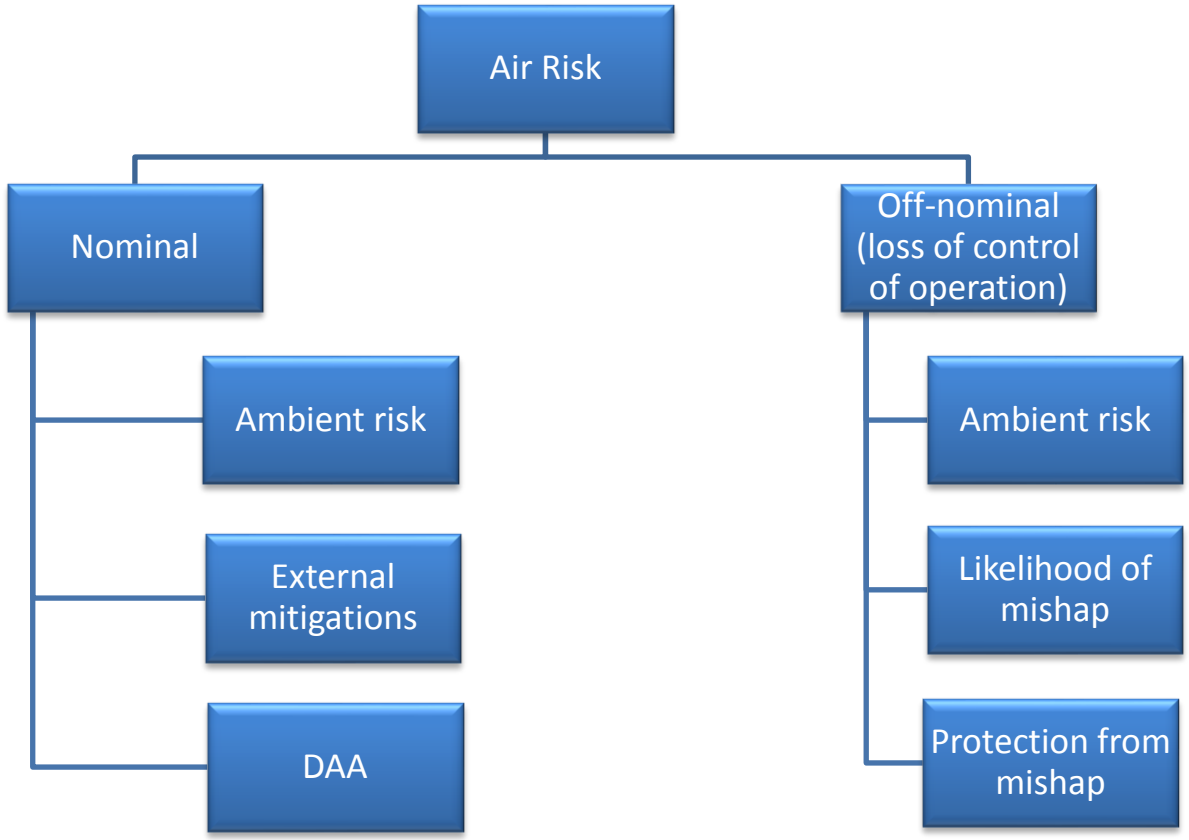
Level of Robustness

What happens if?



Why this happens?

Air Risk Model

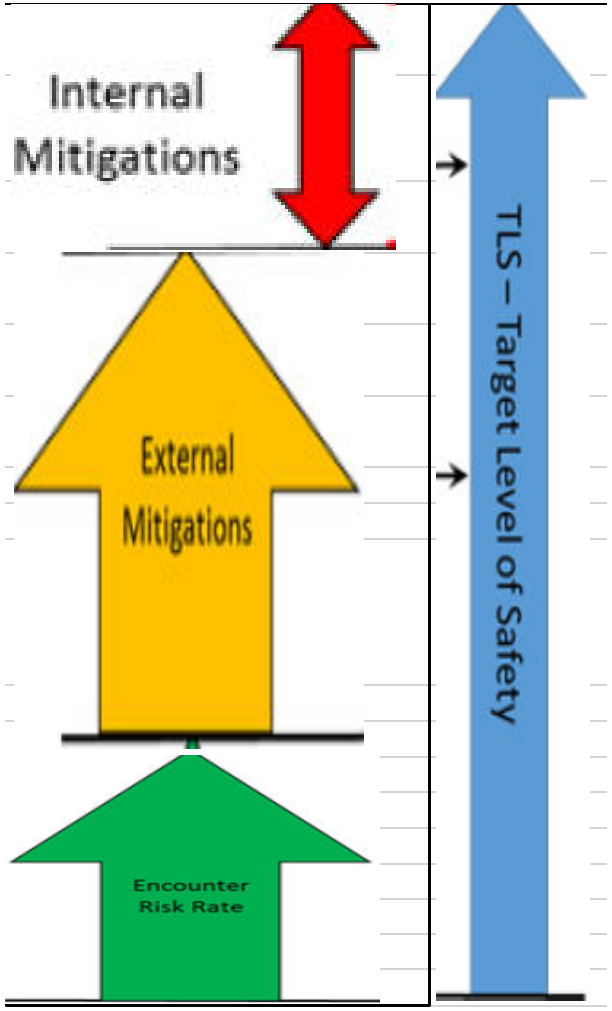


Target Level of Safety

Internal Mitigations
Residual Risk

External Mitigations

Air-Risk Class
Airspace Threat



Qualitative Approach to Air Risk

Risk Factors

- Proximity
- Geometrics
- Dynamics

X

Operational Factors

- Flight rules
- Altitude
- Airspace Type
- Underlying Population

=

Air-Risk Class

Proximity, Geometry, Dynamics

Proximity, Geometry, Dynamics

Proximity, Geometry, Dynamics

Proximity, Geometry, Dynamics

Qualitative Approach to Air Risk

1. **Proximity** - The more aircraft in the airspace, the higher the rate of proximity, the greater the risk of collision.

2. **Geometry** - An airspace which sets or allows aircraft on collision courses increases risk of collision.

3. **Dynamics** - The faster the speed of the aircraft in the airspace the higher the rate of proximity, the greater the risk of collision.

Where to expect Aircrafts

Airspace Encounter Categories (AEC)

- Close to an Airport
- Within a TMZ
- Over Urban Areas
- Over Rural Areas
- South pole / North pole
- Controlled Airspace
- Uncontrolled Airspace
- Above Minimum Flight Altitude
- Below Minimum Flight Altitude
- Stratosphere

Airspace Encounter Categories (AEC)

Very High Risk for Mid Air Collision

- **Close to an Airport**
  - Controlled Airspace
  - Above Minimum Flight Altitude
  - Below Minimum Flight Altitude
- **Within a TMZ**
  - Controlled Airspace
  - Above Minimum Flight Altitude
- **Non Airport Areas**
  - Controlled Airspace

Airspace Encounter Categories (AEC)

High Risk for Mid Air Collision

- **Over Urban Population**
  - Controlled Airspace
  - Above Minimum Flight Altitude
  - Below Minimum Flight Altitude
- **Over Rural Population**
  - Controlled Airspace
  - Above Minimum Flight Altitude
- **Within a TMZ**
  - Below Minimum Flight Altitude

Airspace Encounter Categories (AEC)

Low Risk for Mid Air Collision

- **Over Rural Population**
  - Controlled Airspace
  - Below Minimum Flight Altitude
- **Stratosphere**

Very low Risk for Mid Air Collision

- **South pole / North pole / Sahara Dessert**

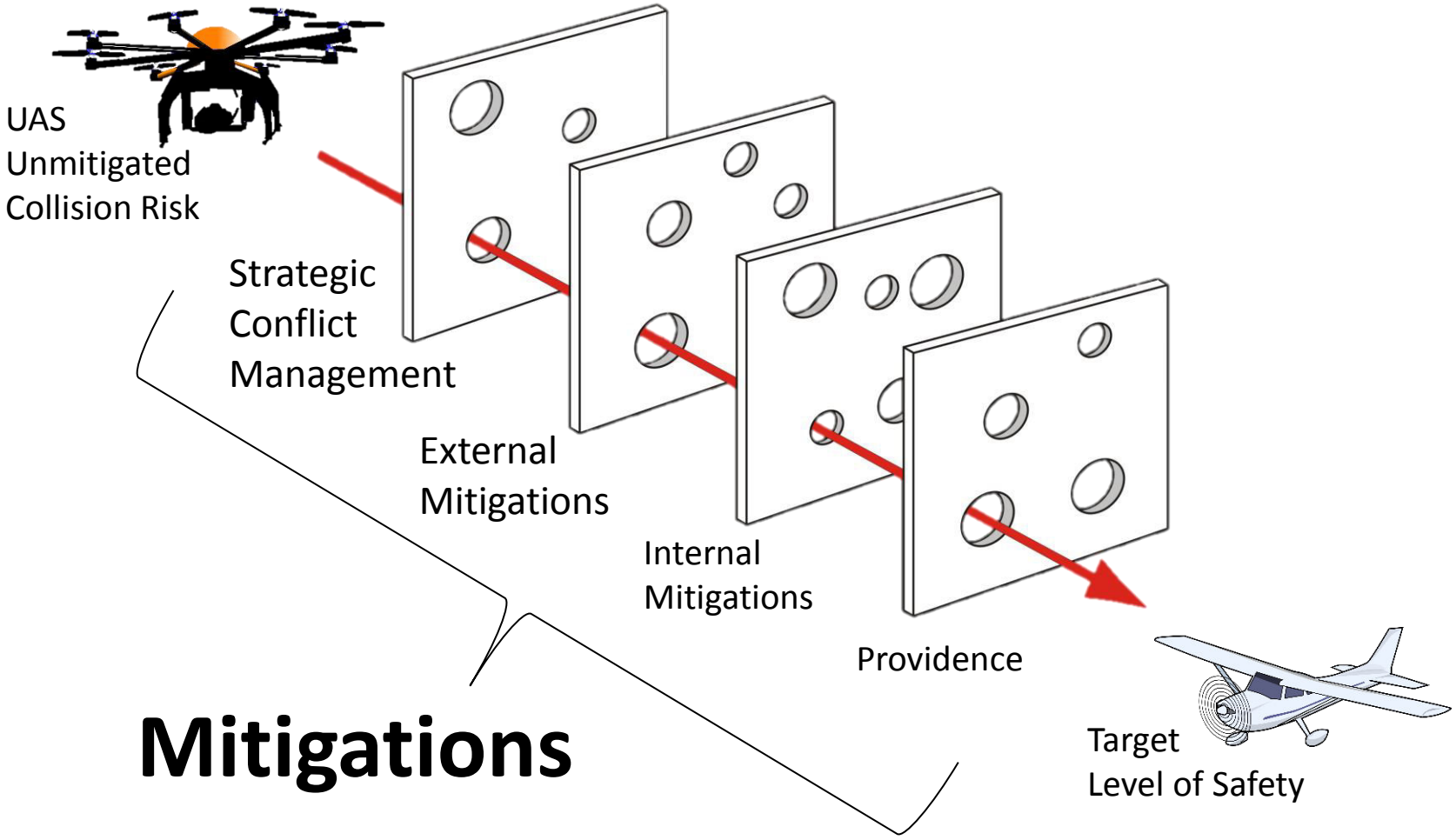
Airspace Encounter Categories (AEC)

Very High Risk for Mid Air Collision	**Risk Class 4**
High Risk for Mid Air Collision	**Risk Class 3**
Low Risk for Mid Air Collision	**Risk Class 2**
Very low Risk for Mid Air Collision	**Risk Class 1**

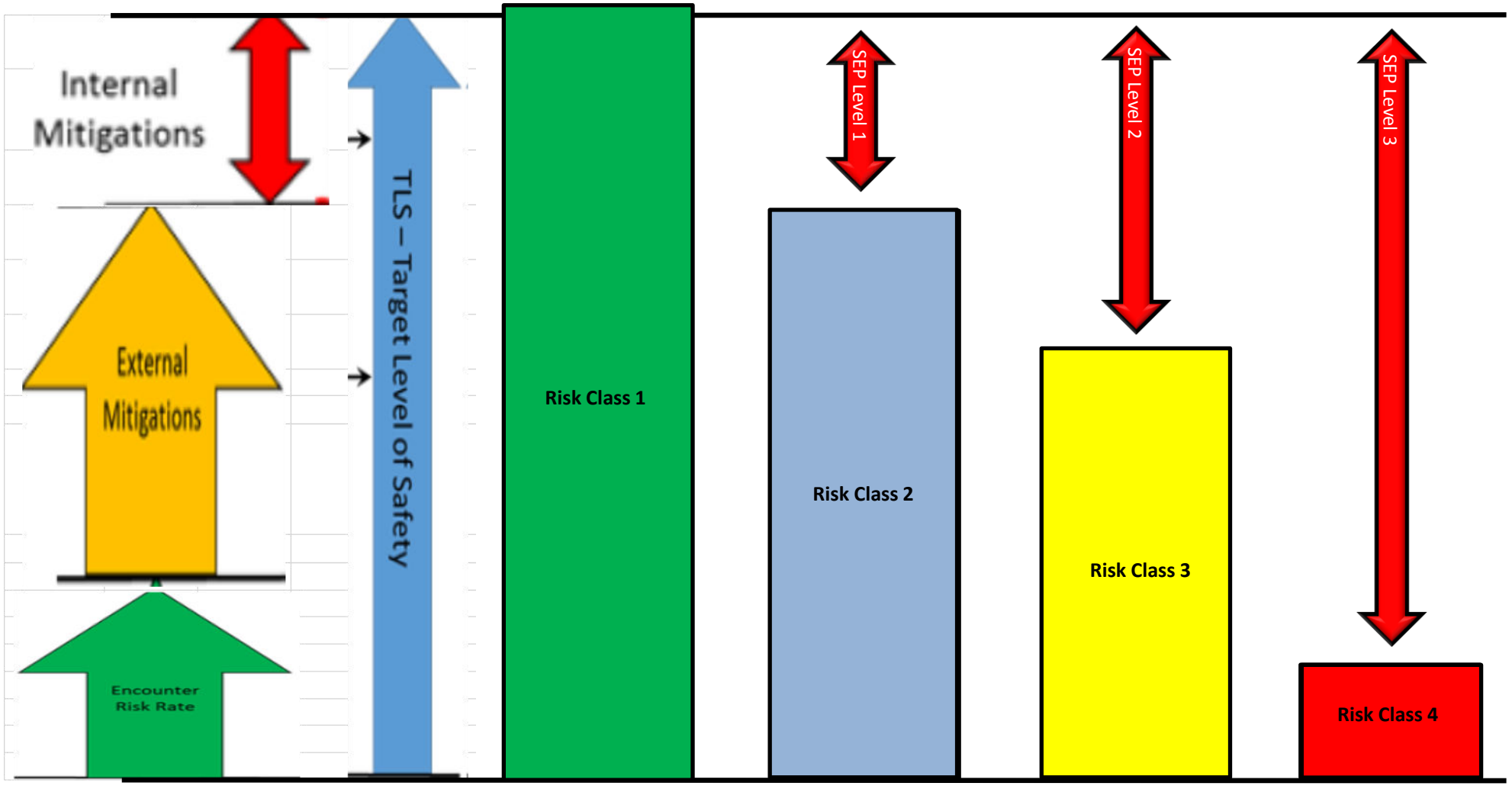
Airspace Encounter Categories (AEC) and Air Risk Class (ARC)

	Airspace Encounter Categories (AEC)	Operational Airspace	Air Risk Class (ARC)
Integrated Airspace Operations above 500 ft.	1	Operations within Class A, B, C, D, or E airspace above 500 ft. AGL	4
	2	Operations within an Airport Environment above 500 ft. AGL	4
	3	Operations within Class G airspace above 500 ft. AGL within Mode C Veil /TMZ	4
	4	Operations within Class G airspace above 500 ft. AGL over urban environment	3
	5	Operations within Class G airspace above 500 ft. AGL over rural environment	3
VLL Operations Airspace below 500 ft.	6	Operations within Class A, B, C, D, or E airspace below 500 ft. AGL	3
	7	Operations within an Airport Environment below 500 ft. AGL	4
	8	Operations within Class G airspace below 500 ft. AGL within Mode C Veil /TMZ	3
	9	Operations within Class G airspace below 500 ft. AGL over urban environment	3
	10	Operations within Class G airspace below 500 ft. AGL over rural environment	2
VHL	11	Operations in airspace above FL600	2
Any	12	Operations in Atypical Airspace	1

Reason mitigation model (Swiss Cheese)



Air-Risk Class and strategic mitigations



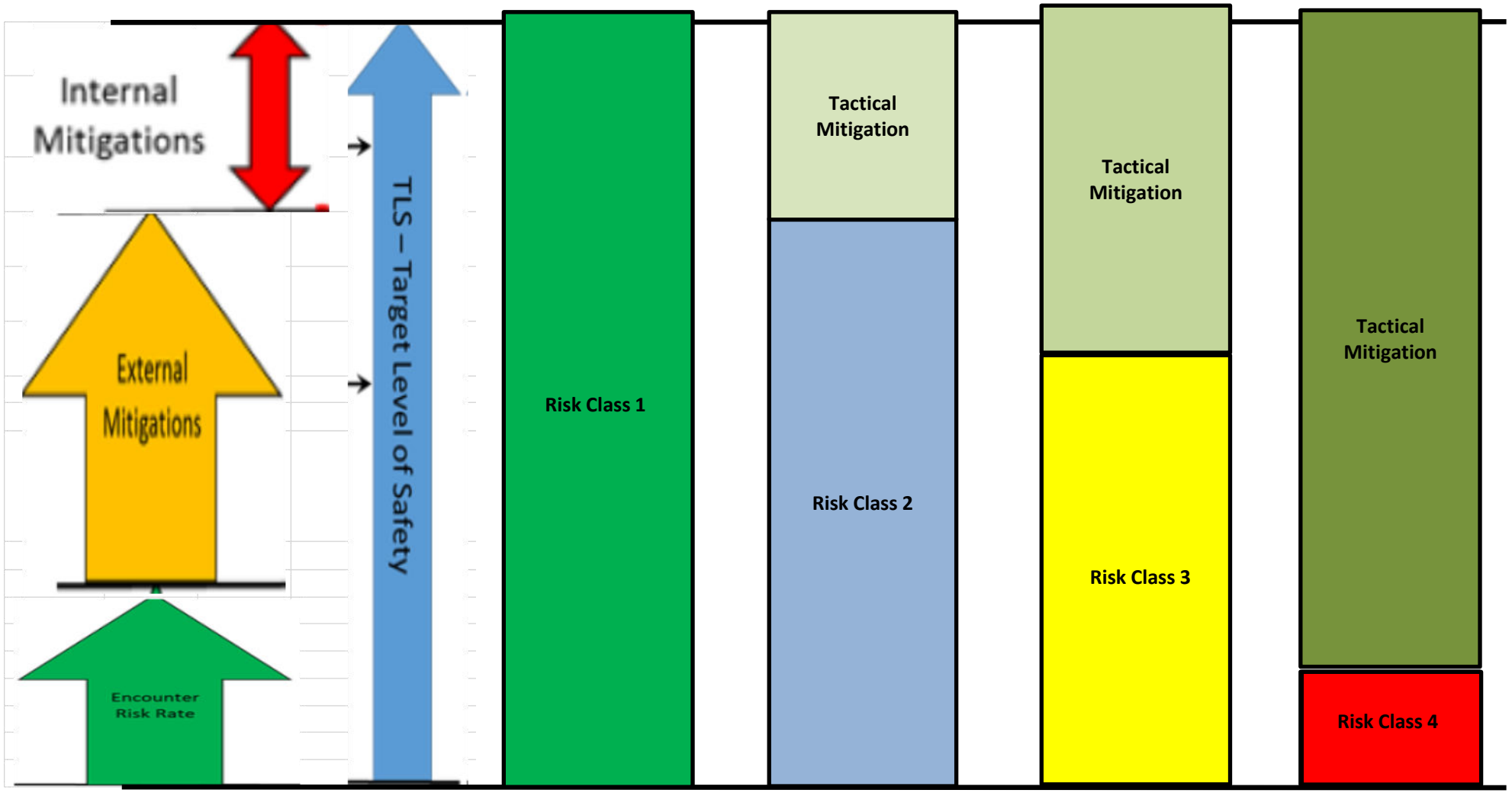
Specific Assurance and Integrity Levels (SAIL)

Air Risk Class	Specific Assurance and Integrity Level (SAIL)
ARC 4	SAIL VI
ARC 3	SAIL IV
ARC 2	SAIL II
ARC 1	SAIL I

Specific Assurance and Integrity Levels (SAIL)

Deterioration of external systems supporting UAS operation	I	II	III	IV	V	VI
Procedures are in-place to handle the deterioration of external systems supporting UAS operation	L	M	H	H	H	H
The UAS is designed to manage the deterioration of external systems supporting UAS operation	L	L	M	H	H	H
External services supporting UAS operations are adequate to the operation	L	L	M	H	H	H

Air-Risk Class and tactical mitigations



Tactical Mitigation, Performance Levels

Air Risk Class	Tactical Mitigation Performance Requirements (TMPR)
ARC 4	High Performance
ARC 3	Medium Performance
ARC 2	Low Performance
ARC 1	Optional - the operator/applicant may still need to show some form of mitigation as deemed necessary by the local authority/qualified entity

Robustness Levels

	Low Assurance Level	Medium Assurance Level	High Assurance Level
Low Integrity Level	LOW	LOW	LOW
Medium Integrity Level	LOW	MEDIUM	MEDIUM
High Integrity Level	LOW	MEDIUM	HIGH

3 Pillars of a new Risk Assessment

- **Risk Based Approach. What are the real Risks of the Operation**
- **New Culture. Holistic not Atomistic**
- **A Total Hazard and Risk Assessment**

QUESTIONS?