Regulating Airworthiness/Spaceworthiness of Future Suborbital Commercial Spaceflight (SCS) Vehicles

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Scope

- Acceptable Levels of Risk
- Review of COMSTAC Roadmaps (series/sequential approach)
- Proposed ‘Parallel’ approach to Air/Space-worthiness

Acceptable Levels of Safety

- Aircraft: Hull Loss Rate – 1 in 10 million per flight
  - (equivalent of 0.01 accidents per 100,000 flights)
- P2P Supersonic (Boom) – initially somewhere here (acceptable)?
  - Equivalence for 1 in 100,000?
- North Sea Helicopter Ops (transportation of workers)
  - 1.35 accidents per 100,000 flights
- Military Fast Jet Target
  - 2 per 100,000 flights; (better reliability now and less low level ops and combat missions)
- P2P Hypersonic (JAXA/DLR/LAPCAT HST Spaceplane) – initially somewhere here (acceptable)?
  - Equivalence for 1 in 50,000?
- UAVs (Reaper/Predator)
  - 3 accidents per 100,000 flights
- Current Suborbital Vehicles – somewhere here (acceptable)?
  - Equivalence for 1 in 5,000 would be 20 accidents per 100,000 missions
  - Probably nearer 1 in 1000 per mission in early days……
- NASA CCP – targets
  - 1 in 1000 (ascent/re-entry), equivalence 100 accidents per 100,000 missions during ascent/re-entry
  - 1 in 270 overall for 210 day mission 370 accidents per 100,000 missions
- Space Shuttle
  - 1 in 90 per mission (1000 accidents per 100,000)

WONG FAA

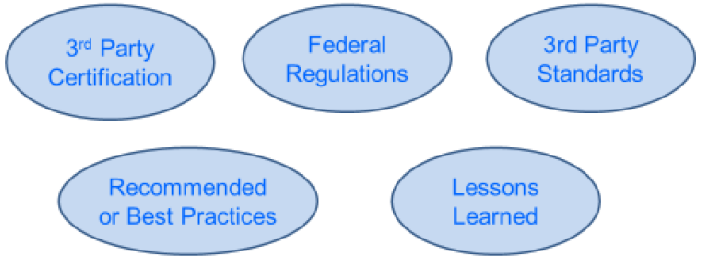
- From Ken Wong, FAA-AST Licensing and Safety Division Deputy Manager, 2007:
  - Overall historical HSF fatal accident rate is based on number of fatal accidents divided by total number of launches with crew or space flight participants.
    - Includes launches by NASA (Mercury, Gemini, Apollo, Shuttle, etc.) and the U.S. military (X-15), as well as foreign and commercial launches.
    - To date, there have been 5 fatal accidents in 463 crewed orbital and suborbital launches, resulting in an overall historical rate of approximately 1%.
- Commercial HSF fatal accident rate is based on number of fatal accidents during commercial missions divided by total number of commercial launches with flight crew or space flight participants.
  - Commercial launch statistics include both licensed and permitted launches.
  - Commercial HSF fatal accident rate was 0% (2007)
    - 0 fatal accidents in 5 licensed launches with a human on board
    - Note from Ken: The 1% is based on historical and empirical data. This is not to infer that industry will use this number as its design goal; it is anticipated that industry will design to a much higher reliability or lower failure rate
  - Commercial HSF fatal accident rate is probably currently 10% (2017)
    - 1 fatal accidents in roughly 10 permitted launches with a human on board

Hence we now require **no more accidents/mishaps** for the **next 90 launches** with a human on board to be back at 1% - is this achievable??

COMSTAC Roadmap

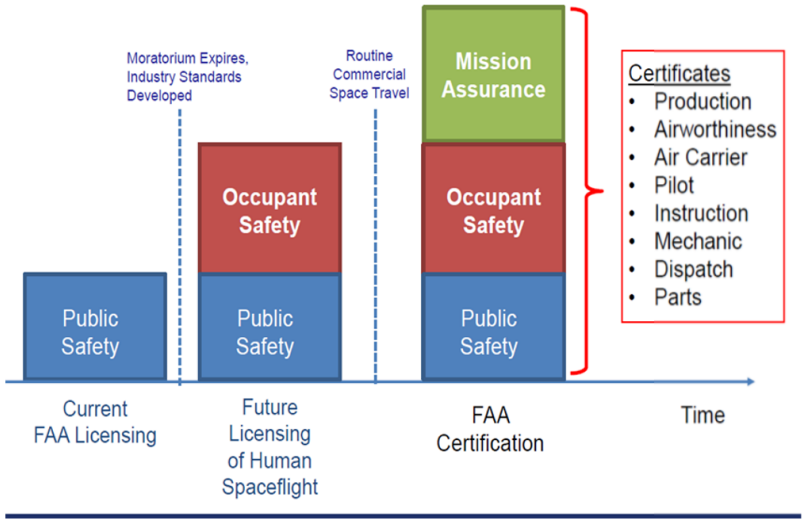
Human Spaceflight Occupant Safety COMSTAC SWG Road mapping

Potential Roadmap Subject Areas



TIMELINE	2015	20XX	20YY	20ZZ
STAGE	LEARNING PERIOD	PRE-REGULATON	REGULATIONS	CERTIFICATIONS
MILESTONE	INITIAL OPERATIONS	ROUTINE OPS	COMMON CARRIAGE	
METHOD	INFORMED CONSENT	NPRM	REGS 14CFR 400.XX	FAA FORMS XXXX-X
INDUSTRY/AST COLAB	SARP	ARC	ARC	FAA=POLICY/VERIF/INSPECT
			INDUSTRY= SARP'S AS MOC	INDUSTRY= SARP'S AS MOC
SAFETY AREAS	DESIGN	DESIGN&PERF	VEHICLES	AIR/SPACE WORTHINESS CERT
	MANUFACTURING	REQD EQUIP	AIR/SPACE CARRIER	COMMON CARRIAGE CERT
	OPERATIONS	QLTYASSURANCE	PILOT/ASTRONAUT	LICENSE
		PRODUCTION	INSTRUCTION	PROGRAM CERT
		OPS MANUALS	MECHANIC	LICENSE
		MAINT&INSP	DISPATCH	LICENSE
		AIRWORTHINESS	PARTS	PMA
	ETC	ETC	ETC	ETC

Potential Regulatory Path



This is in 'series' (a waiting game) over time

Definitions……

- 1st Parties
  - personnel in control of the vehicle
- 2nd Parties
  - persons involved in the SCS but not in control of the vehicle (fee-paying SFPs and additional crew members if applicable)
- 3rd Parties
  - the uninvolved public (those on the ground, in the air or at sea)
    - i.e. 3rd parties does not equal occupants (3rd part certification/3rd party standards……)

Waiting Game

HSF OS Roadmap
Current Industry Input-Draft

2016	2016-20XX	2016-20XX	20XX
MORATORIUM	MORATORIUM	MORATORIUM	LICENSING
INITIAL OPERATIONS	ACTUAL FLIGHTS LAUNCHES	ACTUAL FLIGHTS LAUNCHES	STANDARDS DEVELOPED AND ACCEPTED
INFORMED CONSENT	INFORMED CONSENT	INFORMED CONSENT	HUMAN RATING
	CREW TEST/GOVERNMENT ASTRO/PUBLIC	CREW TEST/GOVERNMENT ASTRO/PUBLIC	CREW TEST/GOVERNMENT ASTRO/PUBLIC
SELF-REGULATION	SELF-REGULATION	SELF-REGULATION	SA'S, DIRECTIVES, BULLETINS, ETC
STANDARDIZATION KICK OFF AREAS	FOR HIRE HSF EXPERIENCE GAINED	APPLICABLE STANDARDS DEVELOPED	HUMAN RATING LICENSING AREAS
DESIGN & ENGINEERING	SAFETY DATABASES		VEHICLE AIRS/SPACEWORTHINESS
MANUFACTURING & ASSEMBLY	REPORTING SYSTEMS		FLIGHT/RANGE, GROUND/ CREW
MAINTENANCE AND REPAIR	KNOWLEDGE SHARING		PRODUCTION
QUALITY ASSURANCE AND TESTING	SAFETY STATS		OPS MANUALS
TRAINING AND TESTING, CREW	INSURANCE REQUIREMENTS		MAINT&INSP CREW
MEDICAL AND FITNESS, CREW	ETC	OPS SPECS	AIRWORTHINESS
MEDICAL AND FITNESS, OCCUPANTS		GROUND	ETC
FLIGHTWORTHINESS		RANGE	
ETC		FLIGHT ATMOSPHERE	
		FLIGHT EX-ATMOSPHERE	
		ETC	

Nice process with NO knowledge. We have <u>50 years of space</u> knowledge involving Human Rated Systems (and more than 50 years in aviation)

Really Real?

HSF Occupant Safety (HSF-OS) Roadmap-Next Steps

- Industry input via COMSTAC/AST telecoms and surveys
- HSF Safety Roadmap REAL drivers:
  - **R**eality- Operational experience gained (metrics and milestones)
  - **E**ffectiveness- practical Industry licensing areas
  - **A**ccord- consensus industry standards, practices, safety data reporting, sharing and management (safety culture)
  - **L**ogic-Licensing levels and timings suitable to type of operation (i.e. flex moratorium periods for adventure, scientific, P2P HSF licensed operations)

Act Now

- Do not wait and do these activities in 'series'
  - How much actual data will be 'learned' with low number of flights; this just extends the period without 'proper'/high level technical requirements
- We should define performance & risk based Requirements + AMC + GM in 'parallel'
  - FAA-AST already has a useful set of GM (it's just nobody is using them because they are not part of the Req's + AMC)

Evolution of SpaceShip2 Regulation

- SS1 – Demo (2004)
  - FAA-AST Launch Permit
- SS2 – Development
  - FAA-AST Launch Permit
  - FAA-AST Launch License – 2018?
- SS3 – 'Certified'/Licensed (2023??)
  - FAA-AST aim to have requirements for humans and mission assurance, but…..
  - Needs rationalised Performance & Risk Based Requirements (with AMC + GM) sooner

ICAO Oversight

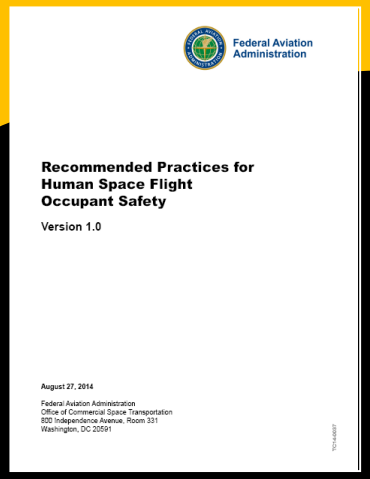
ACCEPTABLE MEANS OF COMPLIANCE

OVERSIGHT

ICAO ----------

Information/Guidance Material ----------Role??

FAA-AST



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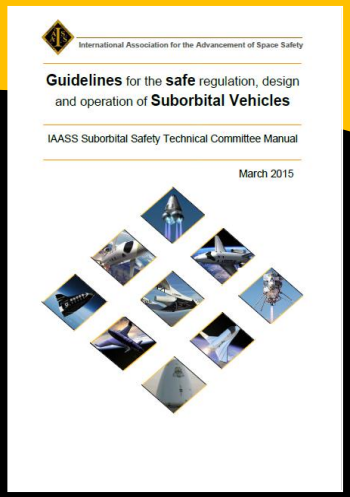

GUIDANCE MATERIAL

Vehicle Requirements

- Performance & Risk Based Requirements
  - (rationalised for suborbital spaceflight)
- Acceptable Means of Compliance (AMC)
  - Without this step, designers/operators may miss vital requirements in their design (3 inhibits for Inadvertent operation for commercial human space vehicles)
- Guidance Material
  - GM to meet the AMC (to meet the Regulatory Requirement)

Existing Example

8.10. Structures-1

The RLV operator should not operate the vehicle beyond its analytically determined structural failure point, consistent with ensuring public safety.

3.2.3 Composite and Bonded Structures

At a minimum, composite and bonded structures, excluding glass, should adhere to the design and test factors specified in table 3.

Table 3. Recommended Minimum Design and Test Factors for Composite and Bonded Structures

Verification Approach	Geometry of Structure	Design Factors	Test Factors	
		Ultimate Strength	Qualification	Acceptance or Proof
Prototype	Discontinuities	2.0*	1.4	1.05
	Uniform Material	1.4	1.4	1.05
Protoflight	Discontinuities	2.0*	N/A	1.2
	Uniform Material	1.5	N/A	1.2

* Factor applies to concentrated stresses.

Rationale: The principal function of the structure is to protect the inhabitants and components of the vehicle from the external environment. Some structural components include, but are not limited to, intertanks, fuselage, wings and control surfaces, engine thrust structures, payload bays and doors, and pressurized crew compartments. The vehicle structure should be designed to preclude failure by use of adequate design safety factors, relief provisions, and safe life characteristics. The vehicle manufacturer should establish a set of operational flight parameters and envelopes which will allow the vehicle not to exceed its structural failure points.

Requirement
(High Level Performance/ Risk Based)

Acceptable Means of Compliance
(To what standard or best practice - Also may suggest Alternative AMC)

Guidance Material
(Rationale and how to achieve the Requirement)

Source: FAA-AST Guide to Commercial Reusable Launch Vehicle Operations and Maintenance, V1.0, 2005

Existing FAA-AST Example

- **§ 460.11 Environmental control and life support systems.**
  - (a) An operator must provide atmospheric conditions adequate to sustain life and consciousness for all inhabited areas within a vehicle. The operator or flight crew must monitor and control the following atmospheric conditions in the inhabited areas or demonstrate through the license or permit process that an **alternate means** provides an equivalent level of safety:
- AMC (states performance-based)
  - Advisory Circular AC No.: 460.11-1-A
    - (Para 5.0); The design considerations provided are based on case histories of aircraft, space craft, or the use of similar ECLSS components for other industrial applications on Earth……
    - (Para 5b); an operator must demonstrate an equivalent level of safety for a system that does not incorporate monitoring or closed-loop control of the atmospheric conditions in question.
    - (Para 6c); While FAA regulations for aircraft are not binding for suborbital space flight, they may be instructive for some applicants…….

NEXT STEPS?

- FAA-AST have been 'restricted' by Congress – ICAO are NOT (also EASA/UK/IT/Fr/UAE)
- We need to discuss alternative approach to where we are all headed i.e. currently in a series/ sequential path of 'learning' before developing 'proper' standards (or regulations)
- Focussed ICAO-led WG to provide independent and international SCS Vehicle Performance & Risk Based Requirements with appropriate AMC & GM (whilst having important lessons fed in by the FAA-AST)
- For individual nations (Regions) – please take advice from your space industry experts (this is not just aviation with a rocket….)

Thank You For Your Attention

Any Questions?

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