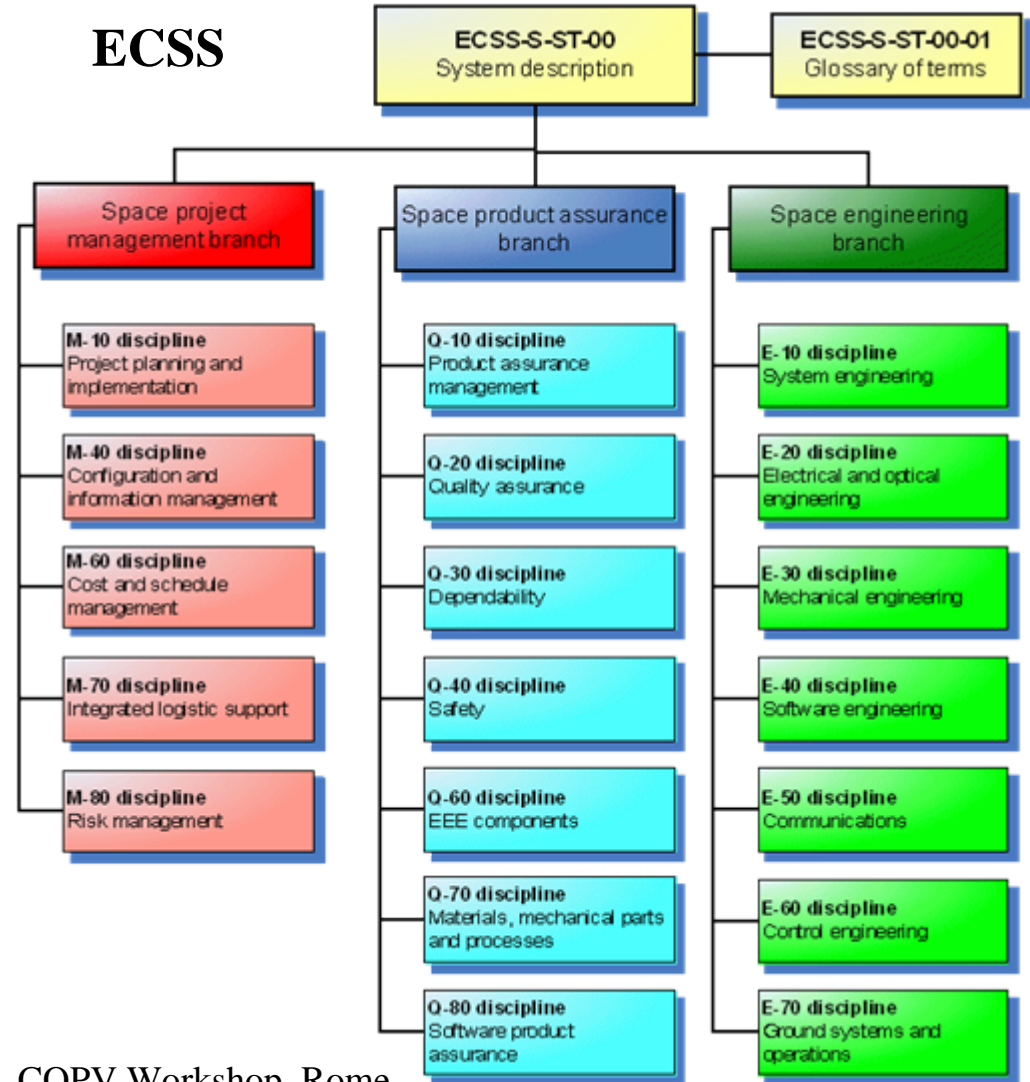


ECSS standard
“Structural design and verification of pressurized hardware”

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Structures Section
ESA-ESTEC

ECSS



- The European Cooperation for Space Standardization (ECSS) is an initiative established to develop a coherent, single set of user-friendly standards for use in all European space activities.
- Members:
 - European Space Agency
 - National Space Agencies
 - Eurospace (industry)

Pressurized Hardware standards

- MIL-STD-1522A “Standard General Requirements For Safe Design And Operation Of Pressurized Missile And Space Systems”
 - Extensively used until recently, but now obsolete
- ANSI/AIAA S-080-1998 “Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components”
 - Replacement of MIL-STD-1522A
- ANSI/AIAA S-081A-2006 “Space Systems – Composite Overwrapped Pressure Vessels (COPVs)”
 - Replacement of MIL-STD-1522A
 - Introduction of specific requirements for COPVs
- ISO 14623 “Space systems — Pressure vessels and pressurized structures — Design and operation”
 - Based on AIAA standards

→ No European Standard !

ECSS-E-ST-32-02C

“Structural design and verification of pressurized hardware”

- defines the structural design verification of metallic and non-metallic pressurized hardware:
 - pressure vessels
 - *Pressurized hardware designed primarily for the storage of pressurized fluid with an energy level greater than or equal to 19310 Joules, or with a pressure greater than or equal to 0,69MPa, or which can create a hazard if released.*
 - pressurized structures
 - *structure designed to carry both internal pressure and vehicle structural loads*
 - pressure components
 - *component in a pressurized system, other than a pressure vessel, pressurized structure, or special pressurized equipment that is designed largely by the internal pressure*
 - special pressurized equipment
 - *pressurized hardware that meets the pressure vessel definition, but which is not feasible or cost effective to conform to the requirements applicable to pressure vessels*

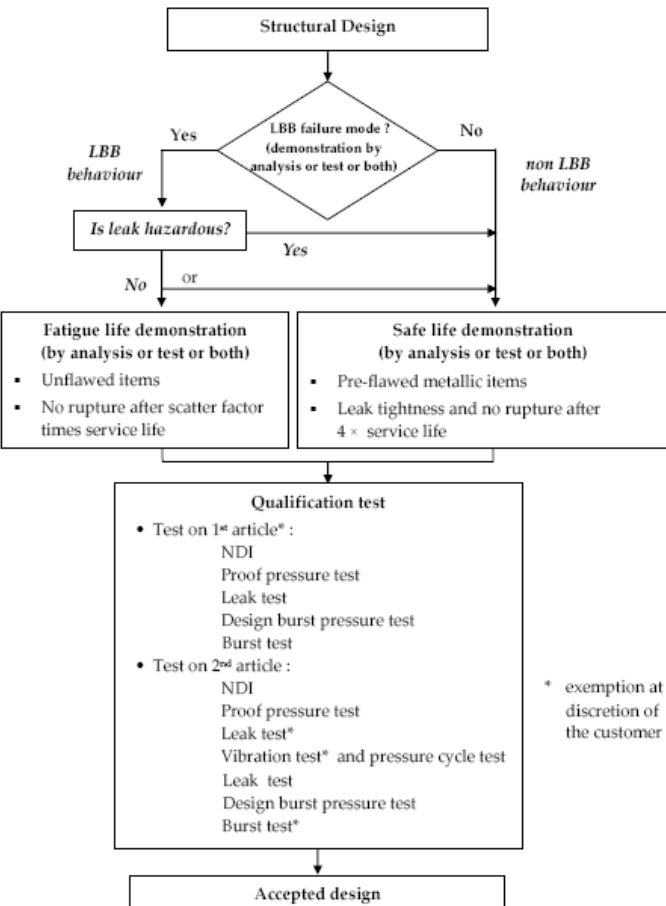
Pressure Vessels (PV)

- Minimum Factors of safety:

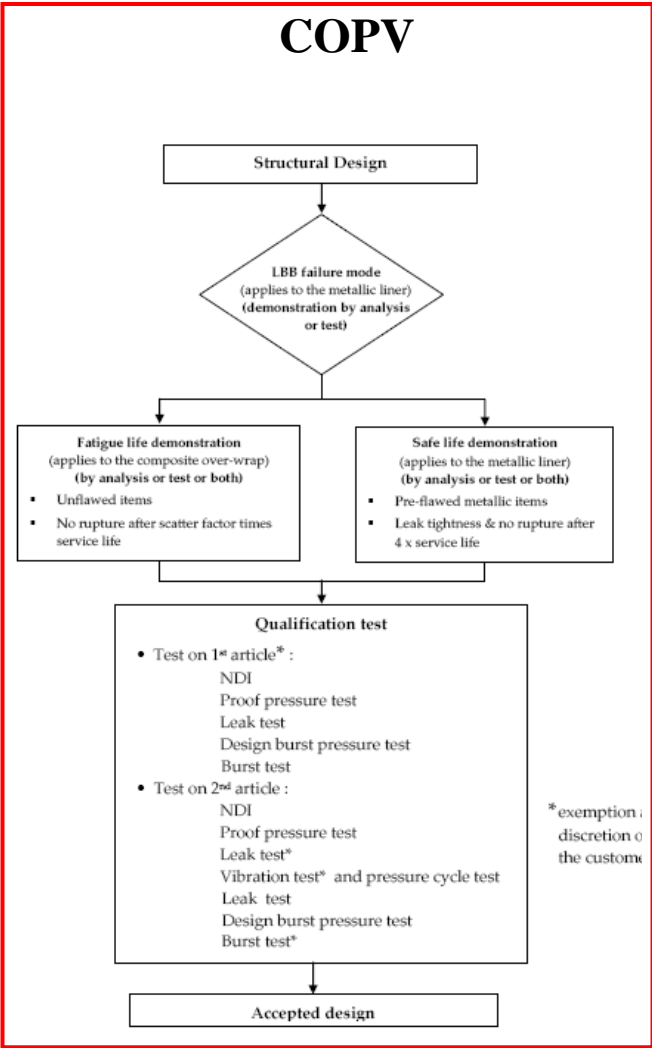
Load	FOSY	Proof factor	FOSU	Burst Factor
Internal pressure	1,0	1,25	1,0	1,5
Mechanical loads (including external pressure)	Values specified in ECSS-E-ST-32-10			

- Three types of Pressure Vessels:
 - Metallic
 - Composite Overwrapped with metallic liner
 - Composite Overwrapped with non-metallic liner or Composite Pressure Vessel

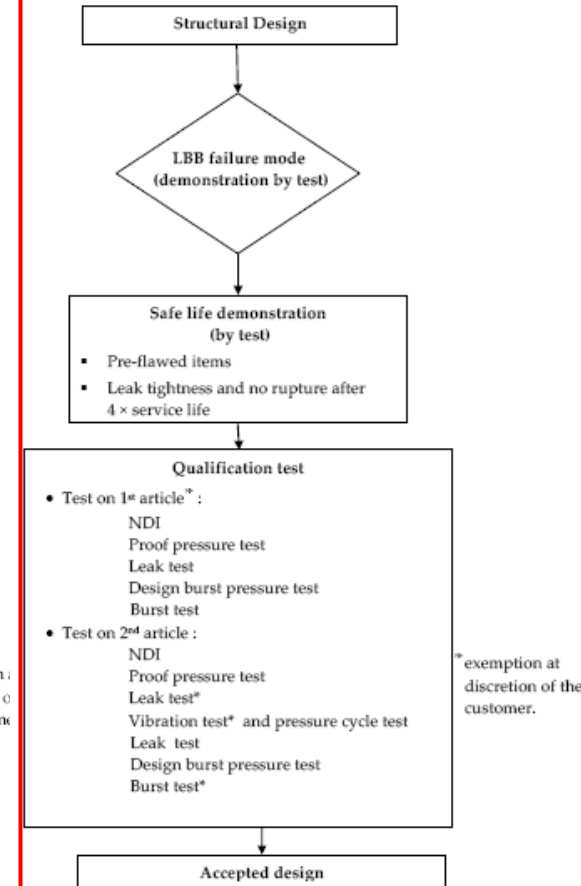
Metallic PV



COPV



COPV/non-metallic



Development approach for Composite Overwrapped Pressure Vessels with metallic liner

- Structural engineering
- Stiffness demonstration (analysis and test)
- Strength and stability demonstration (analysis and test)
- Failure mode demonstration (analysis or test or both)
- Metallic liner shall exhibit LBB failure mode
- Safe-life demonstration for the metallic liner (analysis or test)
- Fatigue life demonstration for the composite overwrap (analysis or test)
- Qualification tests
- Acceptance tests

Structural Engineering

- The COPV shall possess strength such to withstand:
 - proof pressure without detrimental deformation;
 - design burst pressure without experiencing rupture or fibre failure;
 - DYL and simultaneous internal pressure (...) without detrimental deformation;
 - MDP (...) and simultaneous loads multiplied by FOSY for mechanical and thermal loads, without detrimental deformation;
 - DUL and simultaneous internal pressure (...) without experiencing rupture or fibre failure;
 - MDP (...) for internal pressure and simultaneous loads multiplied by FOSU for mechanical and thermal loads, without experiencing rupture or fibre failure;
 - DUL and simultaneous external pressure (...) without experiencing rupture or fibre failure when when pressurized to the minimum anticipated operating pressure.
- The COPV shall possess stability such to withstand:
 - DUL and simultaneous external pressure (...) without experiencing collapse when pressurized to the minimum anticipated operating pressure;
 - DUL and simultaneous internal pressure without experiencing collapse.

LBB Failure Mode Demonstration by analysis

- It shall be shown that, at MDP, an initial surface crack with a flaw shape (a/c), ranging from 0,2 to 1,0, meets the following conditions:
 - it does not fail as a surface crack; and
 - it grows through the wall of the hardware to become a through crack with a length greater than or equal to 10 times the wall thickness of the metallic item and remains stable.
- When LBB demonstration is based on a through crack with a length less than 10 times the wall thickness (...), the considered initial crack size shall be justified.

LBB Failure Mode Demonstration by test using coupons

- The flaws shall be surface cracks and the flaw shape of the pre-fabricated surface cracks shall range from $a/c = 0,2$ to $1,0$.
- The initial surface crack size shall be justified.
- Stress (or strain) cycles shall be applied to the specimens with the maximum stress (or strain) corresponding to the MDP level and minimum stress (or strain) kept to zero, or actual minimum stress (or strain), until the surface crack grows through the specimen's thickness to become a through crack.
- It shall be shown that the length of the through crack becomes equal to or greater than 10 times the specimen's thickness and remains stable at MDP.

LBB Failure Mode Demonstration by test using full-scale article

- The type and initial size of pre-fabricated flaws shall be justified.
- For pre-flawed metallic items, the flaws shall be surface cracks and the aspect ratio of the pre-fabricated surface cracks shall range from $a/c = 0,2$ to $1,0$.
- Location and orientation of pre-fabricated flaws shall be the most critical with regard to LBB response.
- Pressure cycles shall be applied to the pressurized hardware, with the upper pressure equal to MDP and the lower pressure greater than or equal to zero.
- After a flaw has grown through the thickness to become a through flaw and leakage has been detected, internal pressure shall be increased up to MDP.
- (...) After above has been met, no burst occurs at MDP and leak rate is equal to or greater than a value defined with customer approval (...).
- The full-scale test shall duplicate the loading and pressurization medium (gas or liquid) of the flight hardware.

Qualification Tests

- Qualification article #1 (may be deleted with customer approval):
 - NDI (overwrap+liner)
 - Proof test (5 minutes)
 - Leak test (30 minutes at MDP or greater)
 - Design burst pressure test (30 seconds)
 - Burst test
- Qualification article #2:
 - NDI (overwrap+liner)
 - Proof test (5 minutes)
 - Leak test (may be deleted with customer approval)
 - Vibration tests (may be deleted with customer approval if enveloped by other qualif. tests)
 - Pressure cycling test (0 to MDP for highest of 50 cycles or 4xplanned pressure cycles)
 - Leak test (30 minutes at MDP or greater)
 - Design burst pressure test (30 seconds)
 - Burst test (may be deleted with customer approval)

Acceptance Tests

- NDI (overwrap+liner)
- Proof test (5 minutes)
- Leak test (30 minutes at MDP or greater)
- NDI (overwrap as a minimum)

Inspection techniques for composite over-wraps and composites

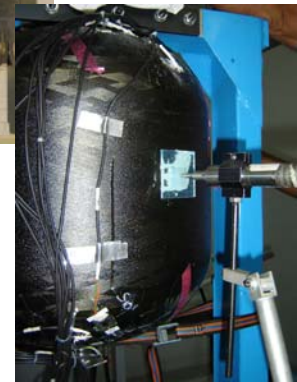
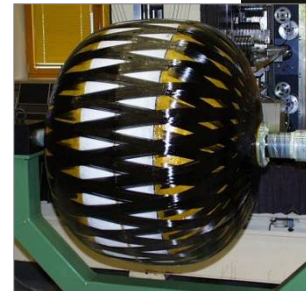
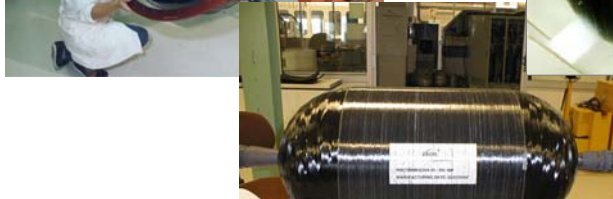
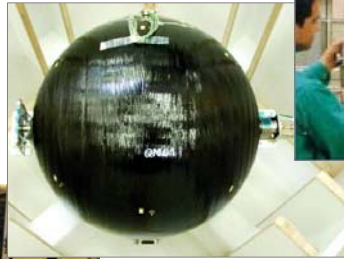
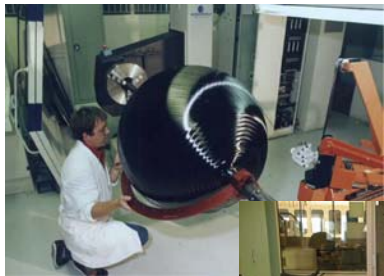
- After application of composite manufacturing process, any composite over-wrapped or composite item of pressurized hardware shall be subjected to the following inspections:
 - visual inspection for detecting impact damage,
 - State-of-the-art NDI technique for inspecting mechanical damage or flaw induced on the composite.
- Visual inspection shall be performed by inspectors, who have been trained to detect visible damage (...) involving the use of actual damaged hardware.
- The NDI procedures are based on using multiple NDI methods to perform survey inspections or diagnostic inspections as follows:
 - survey NDI inspections shall be conducted when the location of the potential damage or flaw zone is unknown;
 - diagnostic NDI inspections shall be performed within a localized suspect zone to characterize the type and extent of the damage or flaw.
- All NDI techniques, whether used as a single inspection technique or as a combination of methods, shall have the capability to detect impact or flaw that can cause the composite over-wrapped or composite pressurized hardware to fail.

ECSS Task Force “Damage Control of COPVs” (1/3)

- Damage Control requirements introduced in AIAA and ISO.
- Decision to include Damage Control requirements in ECSS had to be made taking into account:
 - Safety;
 - Existing European tanks;
 - Current Damage Control capabilities in Europe;
 - Competitiveness worldwide.
- Task force mandate:
 - *To review the present situation of the European composite tanks (...);*
 - *To identify the potential problems linked to non application of damage control requirements to some composite tanks during their development;*
 - *To propose solutions to solve the identified potential problems in order to maintain the ability to use these composite tanks in the European programmes using the ECSS standards and to restore the possibility for the tank manufacturers to sell them on the worldwide market.*

ECSS Task Force “Damage Control of COPVs” (2/3)

- Review of European COPVs (Astrium, MT-Aerospace, Thales-Alenia Space):
 - No damage control requirements for off-the-shelf
 - Damage control requirements for running developments



20/10/08

COPV Workshop, Rome

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ECSS Task Force “Damage Control of COPVs” (3/3)

- Risk for safety recognised.
 - covered as needed by launch and/or range safety authorities
- European satellites prime contractors will apply the Damage Control requirements as required by the launch and/or range safety authorities.
 - Not yet required (nor applied in the US?)
- Risk of loss of competitiveness for off-the-shelf tanks if Damage Control requirements are applicable.
 - some test activities initiated in the US on the subject (White Sands)
- Mitigation plan for implementation of Damage Control requirements:
 - impact tolerance assessment for off-the-shelf telecom satellites COPVs
 - Further development of protective covers to be pursued in Europe
 - Improvement of NDI techniques
 - Training of European personnel for visual inspection of COPVs

→ ECSS Steering Board concluded NOT to include Damage Control requirements

Conclusion

- A new ECSS standard for pressurized hardware has been issued in July 2008
 - www.ecss.nl
- COPVs (and others) are covered by this standard
- ECSS requirements consistent with AIAA/ISO requirements
- No Damage Control requirements implemented.

Questions ?