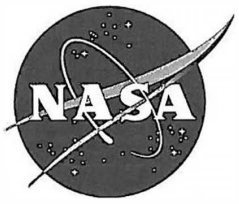
# Damage Threat Assessment (DTA) and Damage Control Plan (DCP) Template for Composite Overwrapped Pressure Vessels

*JSC Engineering Materials and Processes*

Availability: Unrestricted - Approved for Public Release via JSC DAA TN#61452 on 11/28/2018

August 2016




National Aeronautics and
Space Administration

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This document represents the technical consensus of the developing group.

# Damage Threat Assessment (DTA) and Control Plan (DCP) Template for Composite Overwrapped Pressure Vessels

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# FOREWORD

The technical content of this document standard template draws on information contained in NASA/TP-2002-210769 (composite overwrapped pressure vessel test program) and supersedes JSC ES4-10-021.

This is a standard template developed by the National Aeronautics and Space Administration (NASA) Johnson Space Center (JSC) and is intended to provide guidance for developing a damage control plan (DCP) for composite overwrapped pressure vessels (COPVs) used for pressurized fluid storage in ground systems and aerospace pressure systems. This standard template is based on the consensus judgment from Kennedy Space Center, Marshall Space Flight Center and White Sands Test Facility and has been compiled by the NASA JSC Structural Engineering Division Materials and Processes Branch.

This standard template focuses on planning to ensure that COPVs are free from damage through the entire lifecycle, from manufacturing through disposal. The standard template is intended to guide the developer of damage threat assessment (DTA) and the damage control plan in evaluation of credible threats, approaches for protection, establishing inspection points, and disposition of damage that may occur during life. The results of the DTA are used to guide the development of the DCP.

Industry standard requirements related to prevention, inspection and control of mechanical damage are documented in ANSI/AIAA-S-081 Space Systems-Composite Overwrapped Pressure Vessels (COPVs) and the developer of the damage control plan is encouraged to review the latest version of the industry standard and should tailor this template in accordance with the standard, applicable fracture control requirements and any other applicable requirements that have been levied on the project.

The assigned technical authority is responsible to review, negotiate and approve the DCP. If no other assignment has been made the default JSC technical authority is the ES Pressure Systems/Fracture Technical Discipline Lead. Concurrence from the payload/launch site safety authority is needed for COPVs used in many space systems prior to approval.

This standard template was compiled with significant contribution from Mohammed Shoeb/JSC, Nathanael Greene/JSC, Tommy Yoder/WSTF, Joseph Hamilton/KSC, and Jeffery Rayburn/MSFC.

# Damage Threat Assessment (DTA) and Damage Control Plan (DCP) for COPV used in *[Payload/Hardware/Program Name]*

Document Number: *[XXX]*

Date: *[xx/xx/xxxx]*

*[Company Name]*

# Damage Threat Assessment (DTA) and Damage Control Plan (DCP) for COPV used in *[Payload/Hardware/Program Name]*

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*Approved By:*

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*[Title, Company]*
*[e-mail, telephone]*

*[Month day, year]*

# Damage Threat Assessment (DTA) and Damage Control Plan (DCP) for COPV used in *[Payload/Hardware/Program Name]*

## REVISION HISTORY

| Number | Revision Description | Date |
|---|---|---|
| | | |
| | | |
| | | |
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## 1.0 Purpose

This Damage Control Plan (DCP) template is used to evaluate and mitigate defined threats to Composite Overwrapped Pressure Vessel (COPV) [P/N XXX] to be used in *[payload/hardware/program name]*. This plan defines the damage threats to a COPV during manufacturing, handling, test, storage, transportation, in-service use and maintenance, including integration, launch, re-entry, landing and re-flight, as applicable, the steps taken to mitigate the possibility of damage due to these threats and the identification of visual inspection points.

*This template may be used to develop a DCP plan for their COPV or generate a project/program specific DCP from scratch. Each [payload/hardware/program name] provider may add, alter or truncate this DCP template based on the scope of the Project. Large, integrated hardware containing COPVs may need additional developments to this plan to accommodate specialized lifting procedures, translation of structural loads, or transportation methods.*

A draft of the DCP shall be sent to the NASA pressure system/fracture technical discipline lead and the appropriate payload/launch site safety authority for review prior to official release.

## 2.0 COPV Information

The COPV (P/N XXX) for the *[payload/hardware/program name]* is manufactured by *[XXX]*.

The COPV has a maximum design pressure (MDP) of *[XXX]* psia/psig at *[XXX]* °F. The assembly is fully described and documented in the *[Name of the data package]*. A summary of COPV is included in table 1.

**Table 1.**
***[payload/hardware/program name]* COPV Information**

| | |
|---|---|
| COPV Specification | *[AIAA, DOT, ASME, etc.]* |
| Part Number | *[XXX]* |
| Hardware name | *[payload/hardware/program name]* |
| Hardware to be flown on | *[XXX]* |
| Hardware mounting type: | *[band mount, boss mount, skirt mount]* |
| Internal volume | *[XXX liters or cu in]* |
| Liner material of construction | *[Name of Material]* |
| Fiber material of construction | *[Name of Fiber]* |
| Matrix resin | *[Name of Resin]* |
| Operating temperature range of COPV | *[xxx °F - xxx °F]* |
| Operating fluids (internal/external) | *[Name of Fluid]* |
| Nominal operating pressure | *[XXX psia/psig]* |
| Maximum Design Pressure (MDP) | *[XXX psia/psig]* |
| Proof Pressure | *[XXX psia/psig]* |
| Design Burst Pressure | *[XXX psia/psig]* |
| Qualification/Actual Burst Pressure(s) | *[XXX psia/psig]* |
| Design FOS on Ultimate at MDP | *[XXX]* |
| Bonded liner | *[Yes/No]* |

## 3.0 Applicable Documents

ANSI/AIAA S-081A-2006; Space Systems - Composite Overwrapped Pressure Vessels (COPVs)

*[Project may add any document as applicable]*

## 4.0 Reference Documents

Manufacturing and test report for COPV

COPV Inspection Plans *[Company/NASA Inspection Guidelines]*

JSC SN-C-0005 NSTS Contamination Control Requirements

KNPR 8715.3 KSC Safety Practices Procedural Requirements Kennedy NASA Procedural Requirements

*[Document/procedure Number]*; Ground Operations Procedures at *[location, e.g., JSC, KSC, etc.]*

*[Document/procedure Number]*; *[Hardware name]* Experiment Operations Checklist

*[Document/procedure Number]*; Fill Procedure of COPV at *[location, e.g., JSC, KSC etc.]*

*[Document Number]*; *[Manufacturer's name]* Reference for manufacturing and test report of COPV

*[Document Number]*; Range Safety Requirement for *[Launch Range, e.g., Kennedy Space Center (KSC), Air Force, etc.]*

*[Project may add any document/procedure as applicable]*

## 5.0 Acronyms

| | |
|---|---|
| AIAA | American Institute of Aeronautics and Astronautics |
| ASME | American Society of Mechanical Engineers |
| COPV | Composite Overwrapped Pressure Vessel |
| DCMA | Defense Contract Management Association |
| DCP | Damage Control Plan |
| FOS | Factor of Safety |
| ISS | International Space Station |
| ISRP | ISS Safety Review Panel |
| JSC | Johnson Space Center |
| KSC | Kennedy Space Center |
| LBB | Leak-Before-Burst |
| M&P | Materials and Processes |
| MDP | Maximum Design Pressure |
| MUA | Materials Usage Agreement |
| P/N | Part Number |
| PSRP | Payload Safety Review Panel |
| PV/S | Pressure Vessel/System |
| QA | Quality Assurance |
| S&MA | Safety and Mission Assurance |
| SCC | Stress Corrosion Cracking |
| UV | Ultraviolet |
| VI | Visual Inspection |
| WSTF | White Sands Test Facility |

## 6.0 Damage Threat Assessment

A COPV is susceptible to damage due to mishandling during manufacturing, handling, test, storage, transportation, in-service use and maintenance, including integration, launch, re-entry, landing and re-flight. *Each phase should be assessed as to the potential damage sources and the necessary mitigations consistent with a tailored version of Table 2.*

The COPV will be cleaned *[location name]* at filled at *[location name]* to *[XXX psia/psig]* with *[name of the gas]* and integrated into *[payload/hardware/program name]* at *[location name]*. The *[payload/hardware/program name]* will be flown at *[location name]*. The fill procedure and relief valve flow analysis are contained in *[refer to XXX document/procedure for fill procedure, ground filling pressure system schematic and supporting analysis].*

Table 2 needs to be populated to document credible threats mitigations identified as part of the DTA during manufacturing, handling, test, storage, transportation, and in-service use and maintenance, including integration, launch, re-entry, landing and re-flight of the COPV used in *[payload/hardware/program name]* assembly.

Any threats identified in system analyses such as FMEAs, Fault Trees, etc. should be entered into table 2. The listing in the table is not exhaustive.

Design information on materials prone to damage is included in *[Document name/ number or appendix to the DTA/DCP]* addressing the risk of damage due to items such as:

- Material compatibility with internal and external fluids
- Allowable damage criteria substantiated by analysis/test
- Maximum Expected Operating Pressure (MEOP)/Maximum Design Pressure (MDP) for the COPV is $\geq$ the MEOP/MDP of the pressure system in which it is installed

**Table 2.**
**Damage Threat Assessment of COPV used in *[Payload/Hardware/Program Name]***

| Threat | Operation | Pressure Condition | Protection Plan |
|---|---|---|---|
| Over-pressurization of the COPV due to inadequate provisions for control of incoming fluid, inadequate pressure relief or inadequate venting during ground filling | Filling, processing | Up to MDP | This fill procedure has already been tested, qualified and certified at *[location name]*. Fill system shall provide fault tolerant system and relief valve flow analysis for transient peak to prevent over-pressurization *[Refer to XXX document/procedure for fill procedure, ground filling pressure system schematic and supporting analysis]*. |
| Contamination or debris in lines or tank and possible impact damage to COPV interior | Filling, processing | Up to MDP | The system will be cleaned to *[XXX]* for external cleanliness and *[XXX]* level for internal cleanliness. An in-line filter will be utilized during the filling of the COPV. Verification that *[XXX fluid]* is *[XXX percent]* pure *[Refer to XXX document/procedure for filling process and Submittal of manufacturer's certification that supply gas content is XXX percent pure]*. |
| Incompatible materials | Filling, processing, cleaning | Up to MDP | COPV liner, bond and overwrap materials are compatible with *[XXX fluid]*. Material compatibility analysis with testing is *[per M&P document/procedure with XXX approval]*.<br><br>The oxygen or propellants compatibility used on the inside or outside of shall be evaluated and approved by White Sands Test Facility (WSTF) or equivalent *[Refer to document number]* or a MUA will be provided per *[M&P document number]*. |
| Improper workmanship or assembly | Assembly | Up to MDP | The COPV shall be integrated with *[payload/hardware/program name]* assembly per approved design. Payload/hardware shall be assembled per approved design and process control. S&MA/DCMA/QA certification that as-built hardware meets design/specifications *[Refer to XXX]*. |

| Threat | Operation | Pressure Condition | Protection Plan |
|---|---|---|---|
| Handling damage | Manufacturing, filling, handling, test, storage, integration, transportation, in-service use and maintenance | Up to MDP | The COPV will utilize one or more of the following approaches per AIAA S-081A section 5.2.10:<br><br>(a) Protective covers<br><br>(b) Damage indicators<br><br>(c) Worst case threat damage tolerance testing<br><br>(d) visual mechanical damage threshold testing<br><br>COPV to be handled and transported in an approved shipping container in accordance with *[manufacturer's approved procedures, DOT, AIAA, etc. applicable requirements for transportation]*. It is protected from impact damage by commercial packing material such as foam, bubble wrap, anti-abrasion blankets, etc. or a combination of materials which is capable of absorbing the indentation and deflection damage from all potential impact scenarios in the threat environment. Shock sensors are to be placed on the shipping container to quantify the peak forces during the shipping process. The COPV shall be equipped with temperature sensors to maintain the temperature limits defined in the general over/under temperature section of the threat table. Desiccant bags are placed to prevent moisture buildup on sensitive components during the shipping process. Inert, dry pad pressures of 25 ± 10 psig are recommended to ensure internal exposure control *[Refer to manufacturer's spec, fill location safety requirements document/procedure number, and experiment operations checklist document/procedure number]*. |
| Tool impacting COPV | Manufacturing, filling, handling test, storage, integration, transportation, in-service use and maintenance | Up to MDP | The COPV and subsequent assembly are classified as fracture critical and shall be handled according to manufacturer's and hardware owner's instructions *[Refer to XXX, JSC, KSC etc. document/procedure]*. |
| COPV impact (floor/other) | Handling, inspection, lifting, integration | Up to MDP | All movement of COPV is covered by lifting and handling, procedures by using approved lifting and handling hardware *[Refer document/procedure]*. |

| Threat | Operation | Pressure Condition | Protection Plan |
|---|---|---|---|
| Exterior corrosion | Handling, storage, testing and in-service use | Up to MDP | The liner is made of *[liner material]* and the COPV will be used in *[program]*. Exterior corrosion control must be maintained according to cleanliness threat mitigation *[Refer to M&P document/procedure number]* or a Materials Usage Agreement (MUA) will be provided per *[M&P document/procedure number]*. The COPV shall be inspected by a qualified inspector before putting on the protective cover per section 7.0 and 9.5 of the DCP *[Refer to inspection plan document/procedure number]*. |
| Beyond temperature limit | Manufacturing, filling, handling test, storage, transportation, in-service use and maintenance | Up to MDP | During all phases of assembly, integration and flights, the COPV must be kept within the manufacturer recommended temperature limits *[XXX °F - XXX °F]*. Pressurization and de-pressurization of the COPV must be kept at or below *[XXX psig/min.] [Refer to XXX document/procedure]*. |
| Ultraviolet damage (UV) | Manufacturing, filling, handling test, storage, transportation, in-service use and maintenance | Up to MDP | Assembly is kept in shipping container or is shielded from UV light until installation into the pressure system *[Refer to manufacturer's spec and Experiment operations checklist document/procedure number]*. |
| Interface damage (galling for threaded fitting) and damage to the sealing surface | Manufacturing, filling, handling test, storage, transportation, in-service use and maintenance | Up to MDP | Inspections performed before and after interface connections are made. *[Refer to QA certification that as-built hardware meets design/specifications]*. |
| Composite Surface Abrasion | Filling, handling, testing, storage, transportation, integration, in-service use and maintenance | Up to MDP | The COPV shall be restrained using manufacturer recommended corrosion resistant mounting bracket with the rubber gasket materials and recommended torque values *[XXX ft-lb]*. The tank mounting system is able to accommodate the expansion and contraction of the tank without inducing excessive loads to the bracket or causing abrasion to the tank. The nut used in the mounting bracket is equipped with self-locking feature. The mounting bracket is not installed when the tank is pressurized *[Refer to manufacturer's spec, drawings, Experiment operations checklist document/procedure number]*. |
| Corrosion and Buckling | Manufacturing, Pressure/leak testing, In-service use and Maintenance | Up to MDP | Internal inspection of the COPV by a qualified inspector *[Refer to inspection plan and report number]*. |

| Threat | Operation | Pressure Condition | Protection Plan |
|---|---|---|---|
| Undetected Damage | Manufacturing, filling, handling test, storage, transportation, in-service use and maintenance | Up to MDP | Using approved inspection techniques and procedures. Inspections are performed a qualified inspector at the inspection points defined in section 7.0 of the DCP *[Refer to inspection plan document/procedure number]*. |

## 7.0 Inspection

Visual inspections of the COPV composite surface shall be completed at the points shown in figure 1 and table 3. Inspections will be performed by a qualified inspector to ensure there is no damage to the composite surface of the COPV.

**Figure 1.**
***[Payload/Hardware/Program Name]* COPV Lifetime Visual Inspection Milestones**

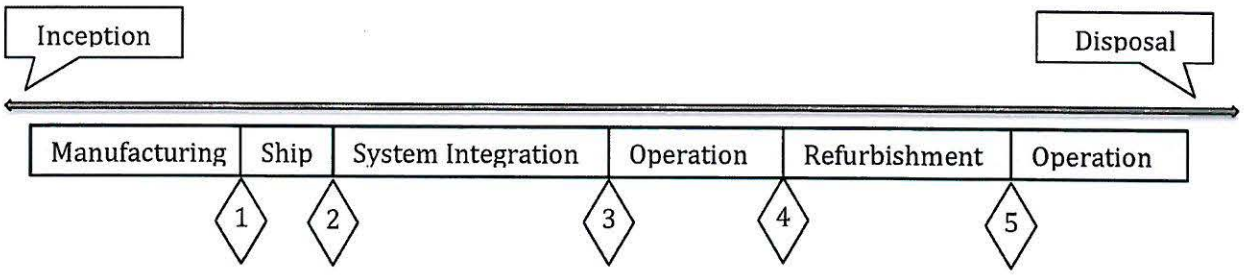


**Table 3.**
**Visual Inspection Table of *[Payload/Hardware/Program Name]***

| Inspection Number | External Inspection | Internal Inspection | Visual Inspection (VI) Description |
|---|---|---|---|
| 1 | x | x | External and internal VI are performed pre and post proof and after completion of manufacturing. External indications post manufacturing such as helical ply angle slippage, broken fiber and fiber tie-off issues and internal indications such as buckles, cracks, lamination, corrosion and contamination shall be dispositioned with the approval of the procuring authority. |
| 2 | x | x | External and internal VI are performed after shipping. External indications post shipping such as mechanical damage, abrasion, cuts and fiber breakage and internal indications such as buckles, cracks, lamination, corrosion and contamination shall be dispositioned with the approval of the procuring authority. |
| 3 | x | N/A | External VI is performed [during x, y, z steps during system integration such as proof tests and system checkout tests. Note, multiple inspections may be required during system integration] and prior to final closeout of the pressure vessel in the system. Damage such as mechanical damage, abrasion, cuts and fiber breakage shall be dispositioned with the approval of the procuring authority. |
| 4 | x | x | External and internal VI (if system is opened) are performed [during x, y, z operations] and after operation prior to refurbishment. External indications such as mechanical damage, abrasion, cuts and fiber breakage, micro-meteoroid orbital debris damage and internal indications such as buckles, cracks, delamination, corrosion and contamination shall be dispositioned with the approval of the procuring authority. |
| 5 | x | N/A | External VI is performed [during x, y, z steps during system integration] and prior to final closeout of the pressure vessel in system. Damage such as mechanical damage, abrasion, cuts and fiber breakage shall be dispositioned with the approval of the procuring authority. |

A COPV inspector may be considered qualified who completes the damage detection training program offered by WSTF or equivalent and has in-house written procedures governing COPV inspector certification (equivalent to level II per AIA NAS 410 or SNT-TC-1A) and is approved by the NASA Pressure Systems/Fracture Technical Discipline Lead and as applicable the appropriate payload/launch site safety authority.

The physical protection (padding) must be in place on the inspection surface prior to the COPV being removed from the shipping container. The COPV is placed gently on a surface prepared with commercial packing material *[such as foam, bubble wrap, anti-abrasion blankets, etc. or equivalent (see Figure 1)]*.

After installation of the COPV in the *[launch vehicle or sub-system],* physical protection shall be maintained around the COPV to the best extent possible to prevent damage during any assembly operations or processing activities. A qualified COPV inspector shall perform and document inspection before and after installation, and prior to the final closeout of the enclosure (e.g., Lexan shield lined with foam, metallic shroud, other instrumentation including heating element etc.) to ensure there is no damage to the COPV and that there are no loose items in the vicinity that could impact the COPV during transportation or in-service use. If the enclosure is re-opened for maintenance or any other purpose the potential for impact damage will be mitigated by re-inspection using a qualified inspector. Subject to approval of the NASA pressure system/fracture technical discipline lead, after the COPV is integrated into a subsystem that provides protection (i.e. doghouse, shroud, etc.), the areas of the COPV protected do not require inspection prior to re-use.

Lifting and handling of the assembly shall follow critical lift procedures as referenced in *[refer to fill location safety requirements document/procedure number and experiment operations checklist document/procedure number]*.

The NASA pressure system/fracture technical discipline lead, system manager procuring authority and the appropriate payload/launch site safety authority shall be notified of any damage/issue affecting the COPV.

The inspection reports shall be documented in the *[payload/hardware/program name]* data package.

## 8.0 Protection Plan

Visual inspections of the COPV are completed by a qualified inspector after shipping, and before full pressurization unless the COPV is closed out and inaccessible, then it shall be conducted the last time the COPV is accessible for inspection. Due to the fracture critical nature of the COPV, and resulting assembly, care must be taken to avoid damage to the structure/COPV. Before the padding and protective covers are installed around the COPV, care is taken to ensure that the COPV remains either in the original shipping container, or is covered at all times by a blanket, in order to protect it from inadvertent impact damage. Once the padding and cover are installed, the COPV is protected from most mishandling damage. Lifting and handling of the assembly shall follow critical lift procedures as referenced in *[KNPR8715-3 or XXX]*.

During transportation of the assembly, care must be taken to ensure that mishandling damage does not occur. If determined to be necessary by the credible threat analysis, shock sensors are to be placed on the shipping container during all shipping operations in order to quantify the peak forces that the assembly was placed under during the shipping process. Corrosion protection measure *[such as desiccant bags are placed between layers of anti-static polyethylene and a water vapor barrier bag to prevent moisture buildup on sensitive components]* are to be used if corrosion is deemed credible by the threat analysis.

During pressure test of the assembly, care must be taken to avoid damage. Before final closeout (permanent padding and/or metallic cover installation), care is required to ensure that the COPV is protected from damage.

The COPV must meet the requirements of *[fill and leak test location safety requirements document/procedure number]*. The assembly is classified as fracture critical and handling procedures shall follow *[XXX document/procedure]*. Integration of the assembly into the *[payload/hardware/program name]* shall follow *[XXX document/procedure]*, and illustrated in *[Figure xxx]*. Any deviation from the defined requirements for safe handling of the COPV and assembly shall be coordinated through the payload developer in order to identify and mitigate threats.

All pressure cycles placed on the assembly must be documented in a dedicated log book.

## 9.0 Reporting

Any damage threat or discrepancies affecting the COPV shall be reported to the NASA pressure vessel technical monitor and the appropriate payload/launch site safety authority. If the COPV is pressurized, all personnel shall be immediately removed from the area and the access shall be restricted until the COPV is safely de-pressurized. The COPV shall not be re-pressurized until cleared by the NASA pressure vessel technical monitor and the appropriate payload/launch site safety authority and declared safe.

## 10.0 Figures and Drawings

*[Add any drawings, models and pictures that provide the details of the COPV and PV/S.]*

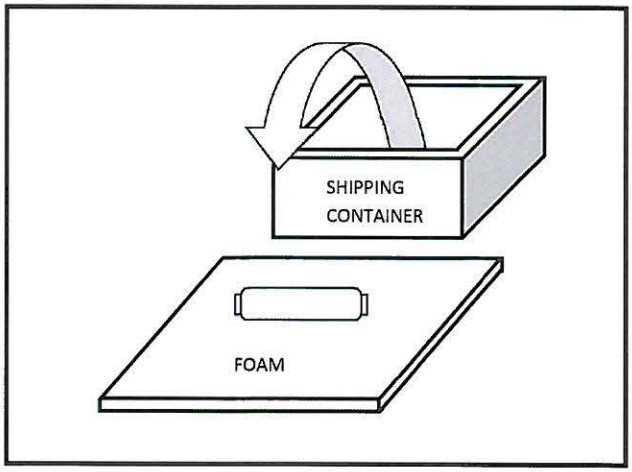


**Figure 2. Physical Protection of the COPV**