

NODE 3 & CUPOLA Thermal Analysis Campaign for Design Verification and Operations Definition

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ABSTRACT

In the frame of the International Space Station (ISS) development plan, TAS-I was in charge of manufacturing, integrating and testing several manned modules like American USOS MPLMs, Nodes 2, Node 3 and Cupola in addition to the European manned modules Columbus and ATV.

Based on the current ISS assembly sequence, Cupola, which is considered a US Governed Furnished Equipment (GFE) of Node 3, will be launched mated to the Node 3 active axial port in the NSTS 20A mission, beginning 2010. After NSTS docking and Node 3/Cupola berthing to N1 Port port, Cupola will be moved and permanently located to the N3 Nadir port to support ISS operations (e.g. Japanese HTV docking maneuvers to N2). Thermal design for Cupola consists of passive protections from launch up to its permanent location and active/passive controls when permanently mated to N3.

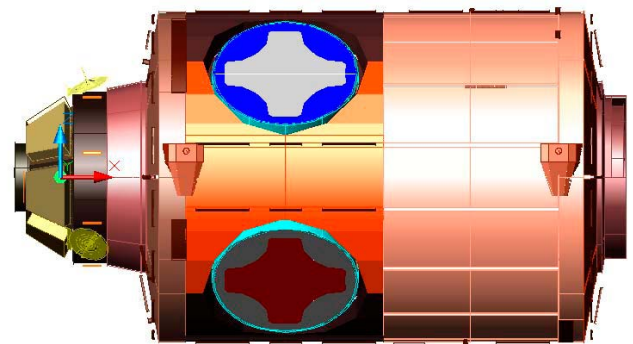
NASA/ESA requested TAS-I to re-study and re-qualify the Cupola thermal design after a relocation and clocking of the Node 3 (from N1 Nadir Port to N1 Port port) to withstand a new launch scenario (Cupola was conceived to be launched stand-alone) and new flight attitudes.

Scope of this paper is to present the analyses being performed by TAS-I to verify the TCS design for Cupola in temporary and permanent locations and show detailed results of humidity and temperature control for Cupola areas associated to Node 3 sinks in terms of air temperature, cabin dew point and water cooling.

All aspects related to the 7 four-pane Cupola windows, in partially or fully open/closed configurations (each window is equipped with thermal/anti-debris shutters), will be matter of this presentation as well, with the intent to highlight when (or if) condensation or over-temperature can occur inside Cupola habitable volumes (structures, skirts, rings and windows) and properly present solutions to prevent crew squawks or discomfort and minimize any safety risk during operative events.

INTRODUCTION

In order to harmonize the ISS Assembly Sequence with the intent to reach the ISS completion by 2010, NASA/ESA exploited NSTS Cargo Capability in such a way to have a single launch to manifest Node 3 and Cupola concurrently as shown in the picture herein.



Cupola was originally designed to be manifested self-standing with the capability of powering the windows heaters during launch and transfer mode if necessary. The new scenario foresees Cupola activation after docking to permanent location only. In this perspective

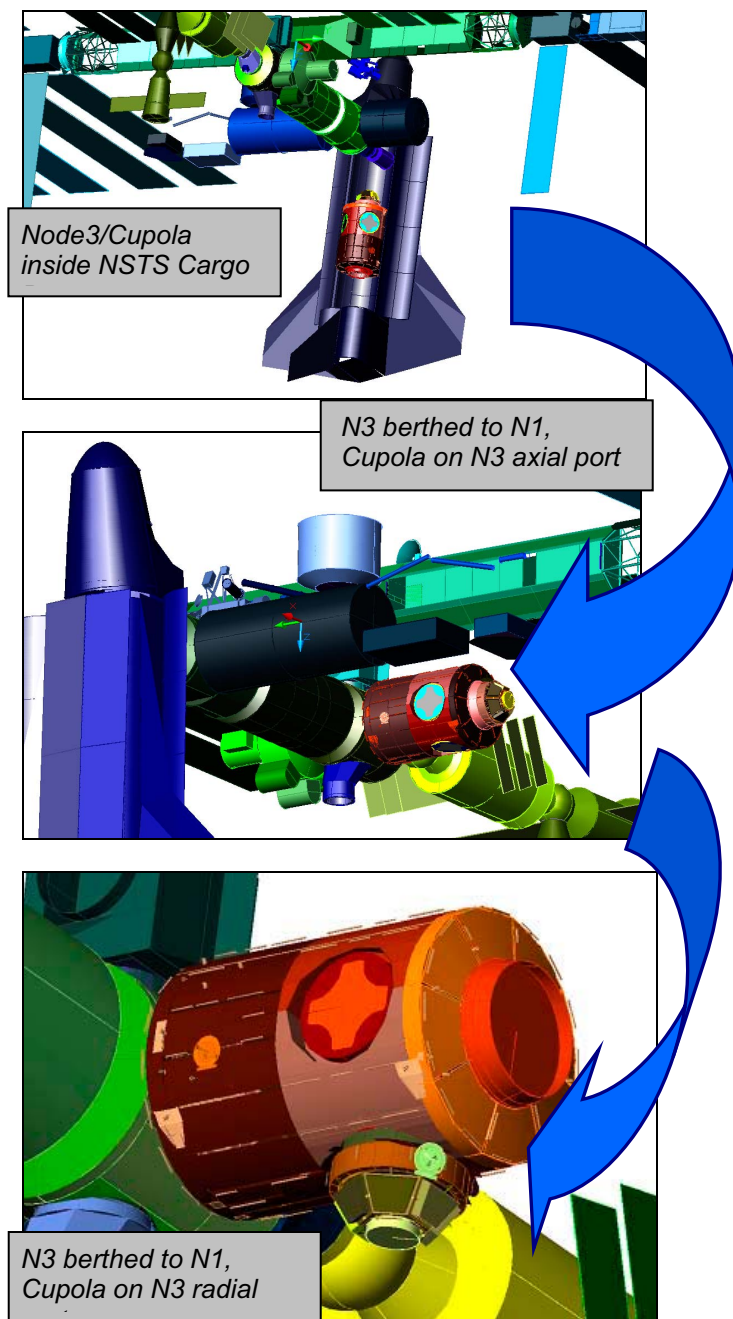
Cupola thermal control is strictly dependant on flight sequence as follows:

- ❖ Passive thermal control during Launch to activation (LTA) via a dedicated MLI cover being designed and manufactured by TAS-I.
- ❖ Active and Passive thermal control on-orbit via coolant received from Node 3 HTL, via IMV fan with air slurped from N3 cabin and re-circulated to Cupola areas and MLI protections.

The resulting thermal design to support Cupola LTA and on-orbit phases and crew needs to open Cupola shutters is matter of this paper.

MISSION SCENARIO PHASES

The Flight 20A LTA consists of the following sub phases:



As far as the LTA phase is concerned with Cupola on AXIAL port (temporary location), it is well worth quoting that Cupola is purged on-ground with dry-air at a dew point of 32 deg F. After berthing N3 to N1 Port port and after N3 activation and crew ingress, the N3 axial hatch facing Cupola will be opened to allow the crew to cap the IMV flange (after removing the saver) mounted at the bulkhead. This operation means that a partial/marginal air recirculation between N3 cabin and Cupola can be expected during the time planned for performing this activity. As a consequence, the probability associated to potential condensation on Cupola structures and window panes (scratch & primary pressure) seems to be very low even though condensation can not be precluded at all. However, when Cupola is depressurized to be moved to the final location on N3 radial (Nadir) port, any moisture will evaporate (flash evaporation phenomenon).

After Cupola mating to Node 3 radial (permanent) port (NADIR), it will be re-pressurized to allow crew ingress for connecting heaters. Subsequently, the Cupola MLI cover will be removed and jettisoned into space during a dedicated EVA currently planned during flight. At the completion of these activities, the Cupola coolant loop will be filled with coolant and finally mated to the N3 HTL (Hot Temperature Loop).

GENERAL REQUIREMENTS AND FEATURES

The analysis campaign being developed to validate the thermal design for N3/Cupola during the LTA and on-orbit phases following N3 relocation was supported by the verification of the driving thermal requirements as follows:

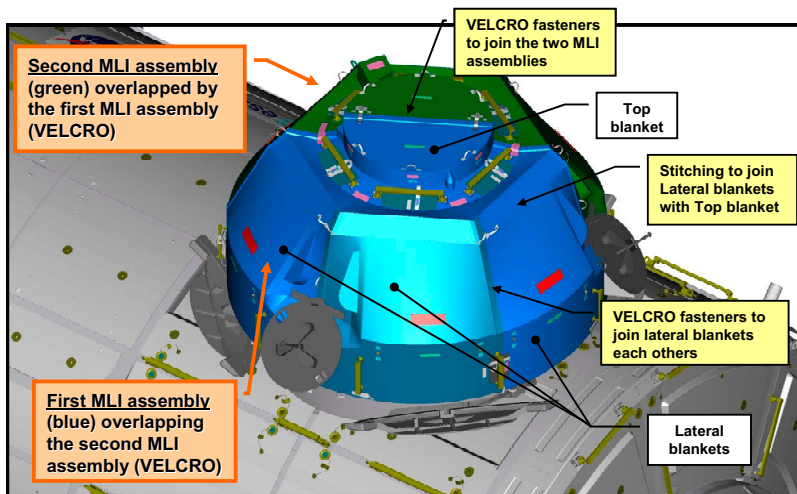
- **On-orbit Thermal Environment** by detailed trade-off and sensitivity analyses to give evidence of N3/Cupola thermal behavior according to flight/stage scenarios, attitudes selection and operative constraints. Some phases have been analyzed in detail to limit crew risks during the demanding EVAs being planned in LTA phases to activate both elements.
- **Component temperatures** assessments never to exceed acceptance temperatures
- **Preclude Condensation** inside Node 3 and Cupola when operated in temporary location on the axial port and when facing N3 cabin via radial Nadir port open hatch in permanent location during on-orbit. In particular, it is well worth quoting that the N3/Cupola relocation was also analyzed in conjunction with an internal synergic reconfiguration of Node 3 based on the integration of new H/W to support crew health and increase personal hygiene. The new H/W that will populate N3 Cabin consist of a new Russian Waste & Hygiene Rack Compartment (W&HC), an Integrated Treadmill Rack (T-2) beneficial for crew physical activity, an Advanced Resistive Exercise Device (ARED) to maintain crew health in space and finally a Total Organic Carbon Analyzer (TOCA) to monitor

concentrations of total organic carbon in ISS potable water samples. All these pieces of H/W when operated by the crew (up to several times a day) increase the heat load injected into the N3/Cupola habitable pressurized volumes in terms of vapor spikes, latent and sensible loads. As a consequence, potential condensation on N3 AND Cupola internal surfaces can occur for transition events associated to the concurrent use of this new H/W.

- **External Touch temperature** for all the items that are planned to be nominally or incidentally touched by the crew during EVAs for both nominal or off-nominal scenarios like handrails, MDPS, MLI, windows, FRGF/PVGF and structures (keels, trunnions).
- **Internal Touch temperature** for all surfaces that can contact the crew inside N3/Cupola
- **Preclude water freezing** for the IATCS/EATCS loops routing inside Node 3 during LTA and that cause a catastrophic event.
- **CBM temperature hold requirement** for allowing PCBM/ACBM mating for N3 to N1 and Cupola to N3. Due to the absence of CBM temperature telemetry, all thermal hold predictions are based on CBM thermal analysis

CUPOLA THERMAL DESIGN DURING LTA

During the LTA phase, Cupola is covered by a MLI blanket fixed via EVA bolts. It will be removed and jettisoned into space after Cupola relocation to permanent position. Both the thermal design and manufacturing have been performed by TAS-I.



The MLI protection consists of two assemblies as shown in picture above) being jointed to each other by VELCRO HI-AIR fasteners, composed with MLI blankets parts stitched together. Each one of the two MLI assemblies consists of:

- 1 top MLI blanket (to cover half of the top window)
- 3 side MLI blankets (to cover of the side windows and MDPS panels of the skirt)

The maximum envelope of the thermal protections composing each assy is the following:

- Top MLI blanket assy; about 1, 9 x 0, 82 m, height 0, 28 m.
- Side MLI blanket assies; about 1.19 x 1.56 m.

Only the two FRGFs and handrails will be uncovered. The MLI Blanket consists of 22 layers of the type with Beta-cloth single aluminized "external layer", according to this composition:

- External Layer: 8 mil Beta-cloth single aluminized.
- Reflector underneath "External Layer": 1 mil double aluminized Kapton (D.A.K) perforated.
- Reflector: 0.3 mil D.A.K. perforated - 19 reflector layers - as internal layers.
- Separator: Dacron net - 20 layers.
- Internal Layer: 0.5 mil D.A.K. reinforced Nomex scrim porolated - side without scrim turn to the structure.

The optical (α/ϵ) properties of the MLI blanket have been measured (at the bench) and injected into the Cupola Thermal Mathematical Model (TMM) being updated to incorporate the actual opticals as driving parameters for thermal protection heat flux balance during LTA phases (based on Thermal Protocol as per Ref. Doc [1]). The following pictures show the Cupola cover nodal breakdown and relevant P/Ns for the different patches.

