Astronaut Thermal Exposure: Re-Entry After Low Earth Orbit Rescue Mission

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Hubble Space Telescope

Photo Courtesy of NASA

STS-125 Hubble Telescope Repair Mission EVA Tasks

Install a new Wide Field Camera 3

Photo Courtesy of NASA

STS-125 Hubble Telescope Repair Mission EVA Tasks

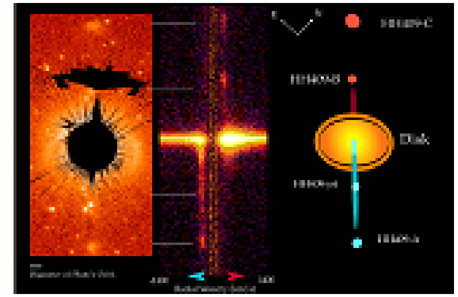
Install Cosmic Origins Spectrograph

Photo Courtesy of NASA

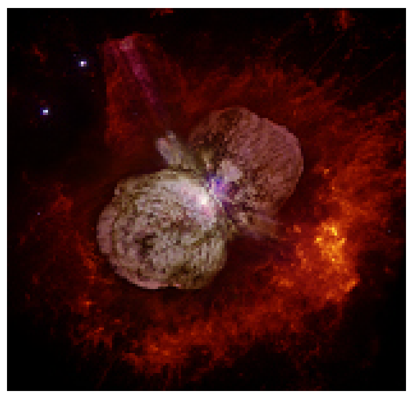
STS-125 Hubble Telescope Repair Mission EVA Tasks

Repair the Space Telescope Imaging Spectrograph

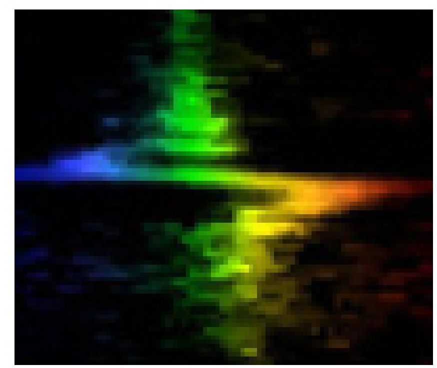
Photos Courtesy of NASA



STIS is capable of probing the complex environment around young stars and their dusty debris disks



The capabilities of STIS were used to study the highly complex eruptive variable star Eta Carinae



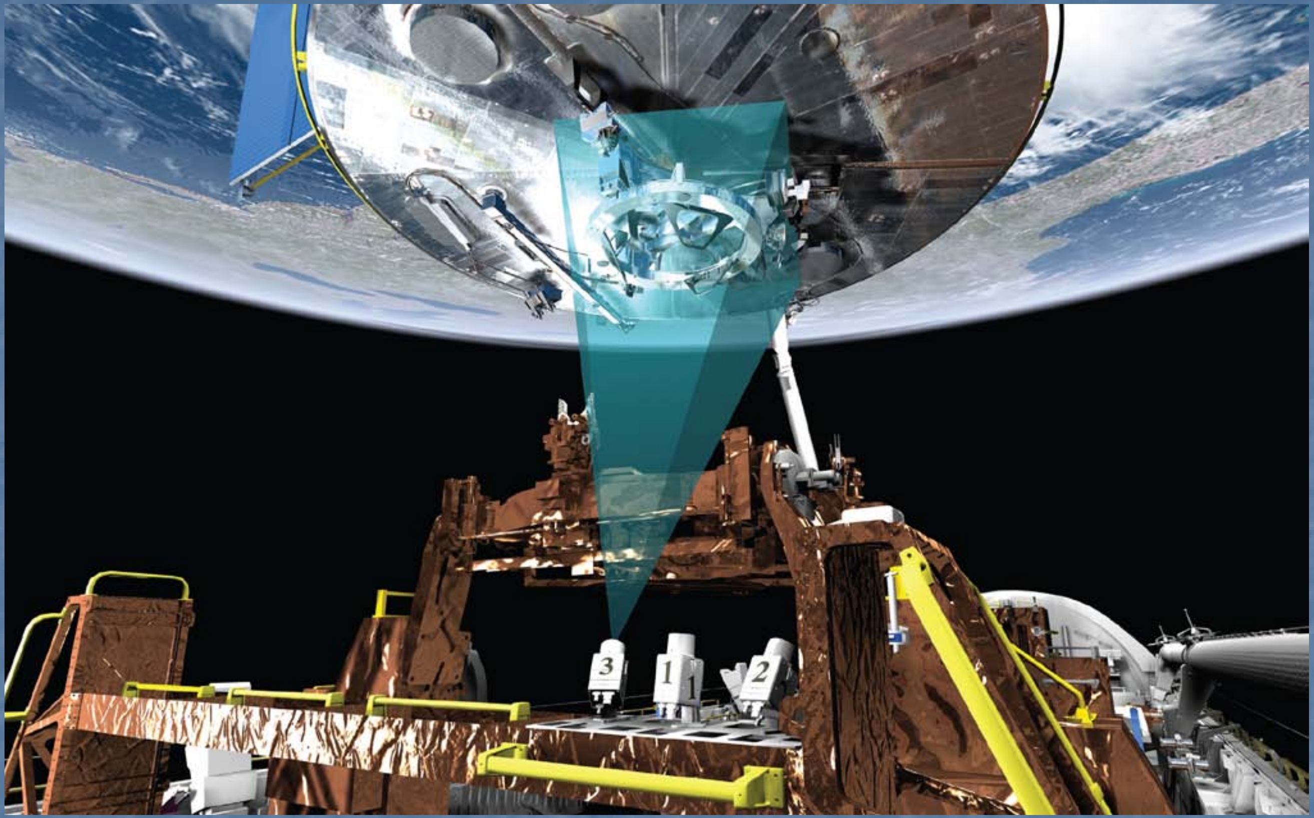
Spectrographic signature of a Black Hole

STS-125 Hubble Telescope Repair Mission EVA Tasks

Install New Outer Blanket Layer

Photo Courtesy of NASA

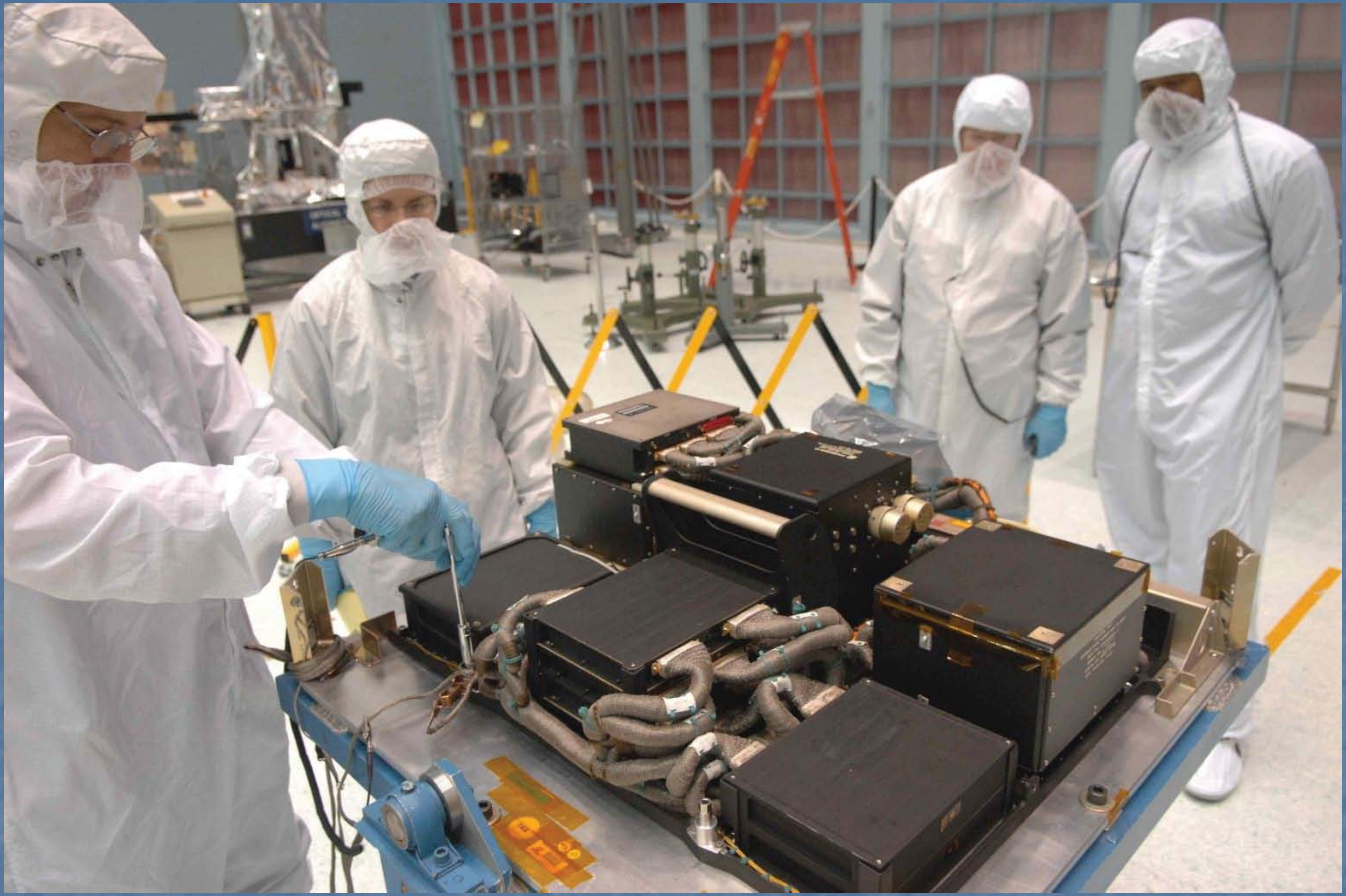
STS-125 Hubble Telescope Repair Mission EVA Tasks



Add a Soft Capture & Rendezvous System for eventual controlled deorbit about 2014

Photo Courtesy of NASA

STS-125 Hubble Telescope Repair Mission EVA Tasks



Replace the “A” side Science Instrument Command & Data Handling module

Photo Courtesy of NASA

STS-125 Hubble Telescope Repair Mission EVA Tasks

Repair the Advanced Camera for Surveys

Photo Courtesy of NASA

STS-125 Hubble Telescope Repair Mission EVA Tasks

Replace Rate Sensor Unit

Gyroscopes

Replace the Fine Guidance Sensors

Replace the 3 batteries

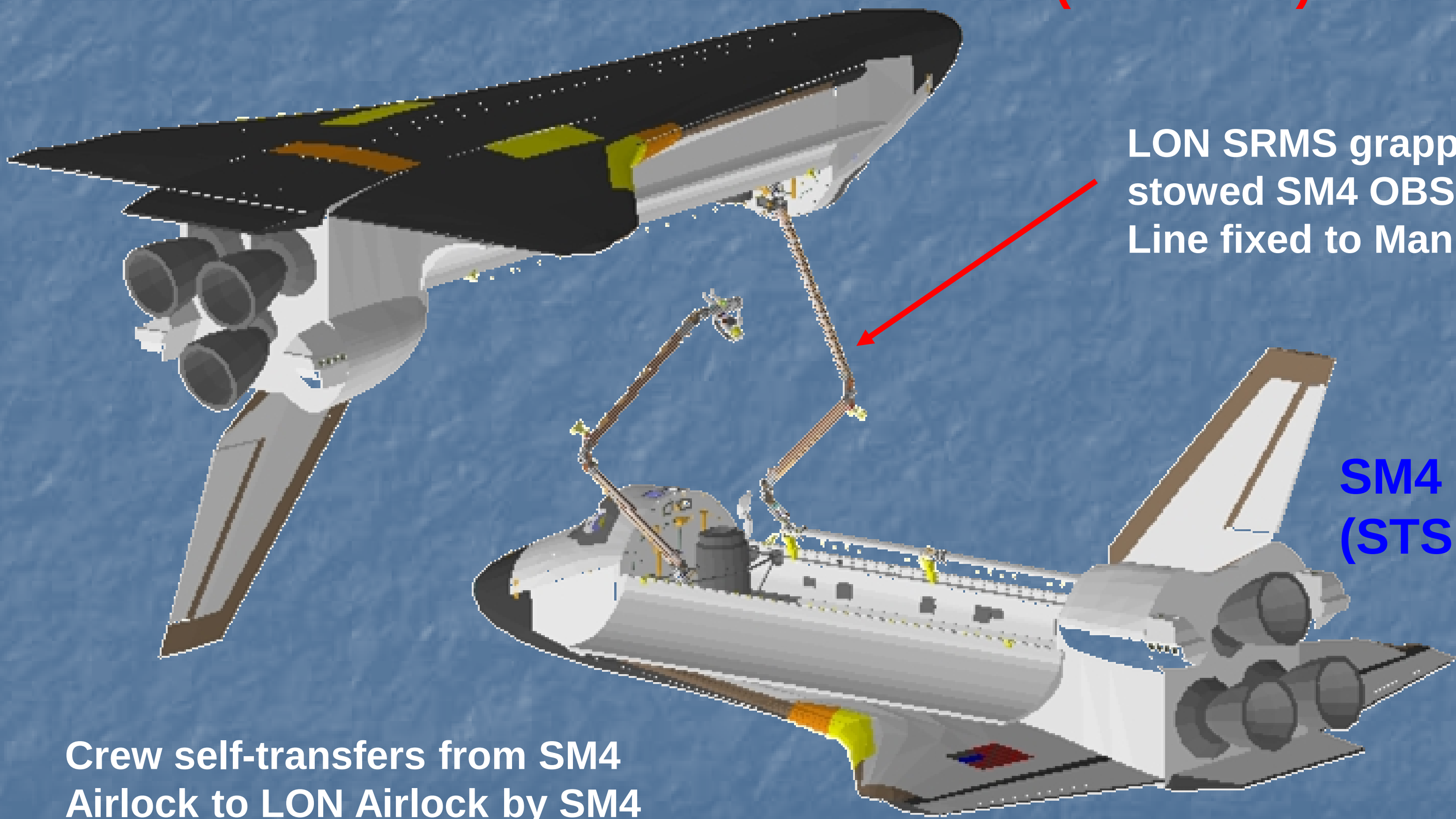
Photo Courtesy of NASA

Shuttle Crew Cabin Thermal Environment

Orbiters oriented at 90 deg angle
Clearance between Orbiters is 30 ft

LON Orbiter
(STS - 400)

LON SRMS grappled to stowed SM4 OBSS EFGF, Line fixed to Manipulator

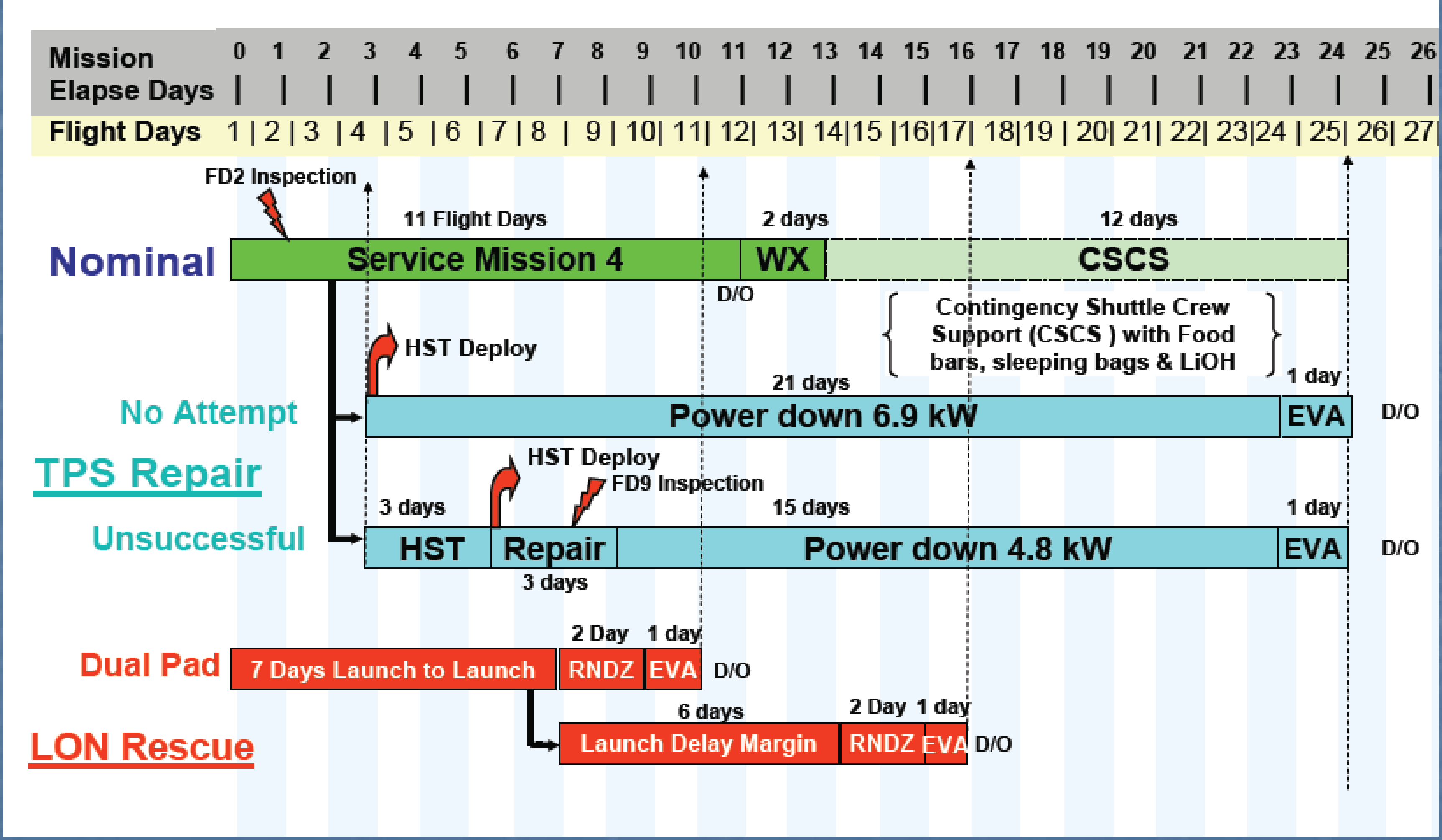


SM4 Orbiter
(STS - 125)

Crew self-transfers from SM4 Airlock to LON Airlock by SM4 SRMS

Graphics Courtesy of NASA

Potential Hubble Repair Shuttle Mission and 'Plan to Fly' Potential Rescue Flight



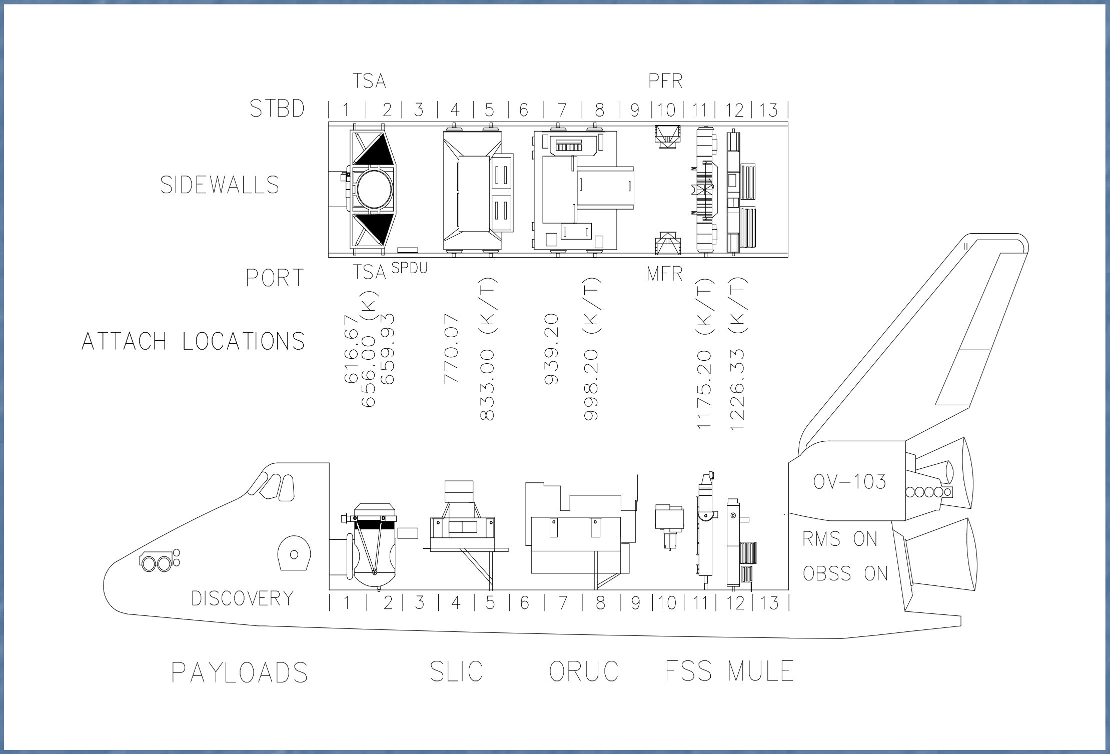
Graphics Courtesy of NASA

Shuttle Crew Cabin Thermal Environment

Nominal SM4 Mission (No CSCS)

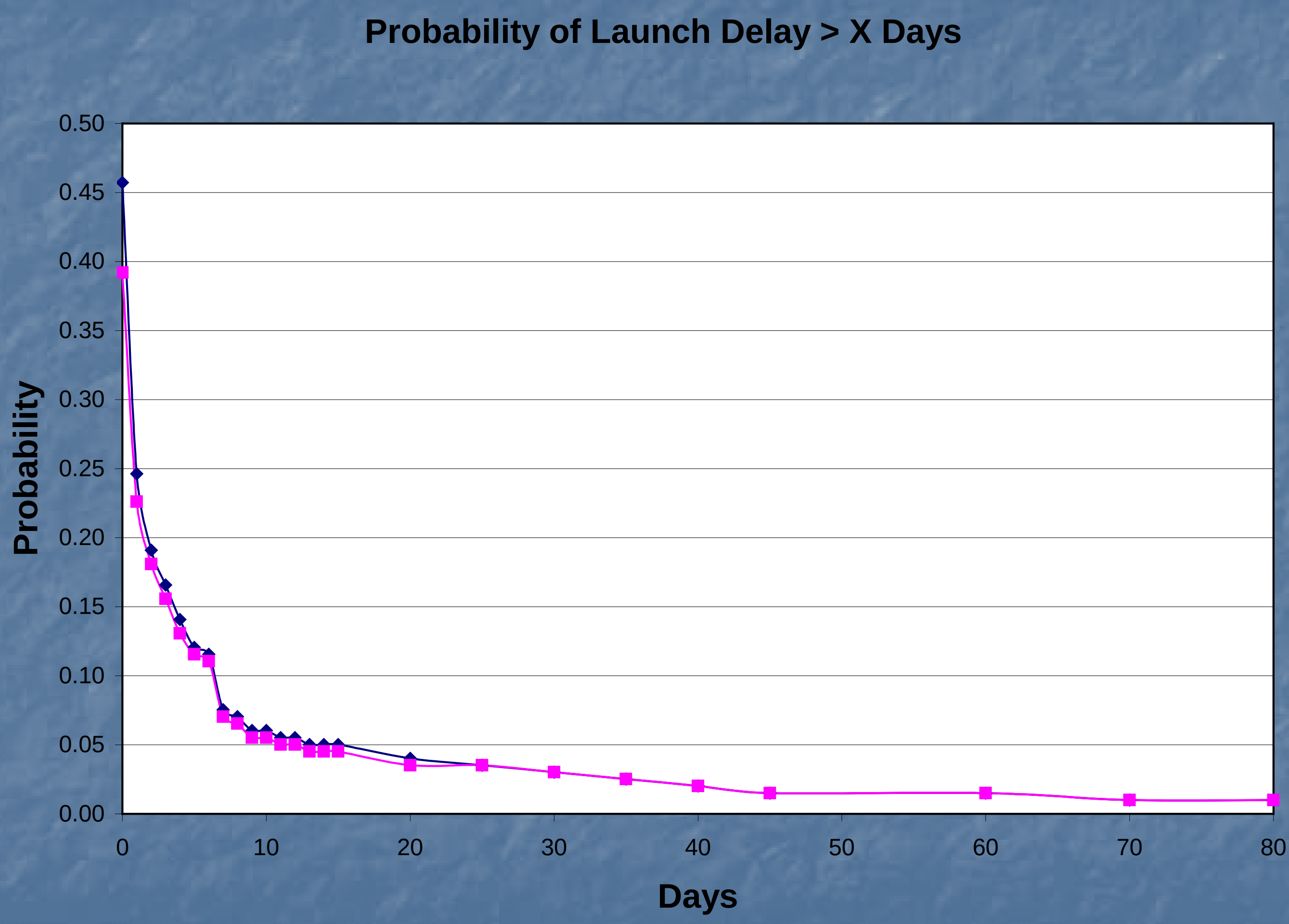
With CSCS Capability

- **Ascent Performance Margin** (vehicle specific)
  - Jan 1402 lbs
  - Feb 1392 lbs
  - Mar 1652 lbs
  - Apr 1742 lbs
- Discovery
- 304 nm Rendezvous Altitude
- 22,500 lbs HST SM4 Control Wt
- 7 crew/11+2 day
- 5 EVAs
- 338 lbs Tile/RCC repair kits
- 1457 lbs Aft Lead Ballast
- 8562 lbs Middeck



Graphics Courtesy of NASA

Shuttle Crew Cabin Thermal Environment



Graphics Courtesy of NASA

Shuttle Crew Cabin Thermal Environment

LiOH CO_2 Scrubbing - 25 Days

# LiOH Canisters	Change-Out Interval
88	Nominal pre- & post-sleep
82	16 hr (FD 10), max 7.6 mmHg
78	16 hr (FD 04) max 7.6 mmHg

ECLSS Requirements

- **N_2 Supply:** about 35 days
- **Supply H_2O Dumps:** 7 KW Power Level)
  4 Dumps for 25 days
- **Waste H_2O Dumps** based on nominal waste generation rate for 7 crew, 9 dumps required for 25 days

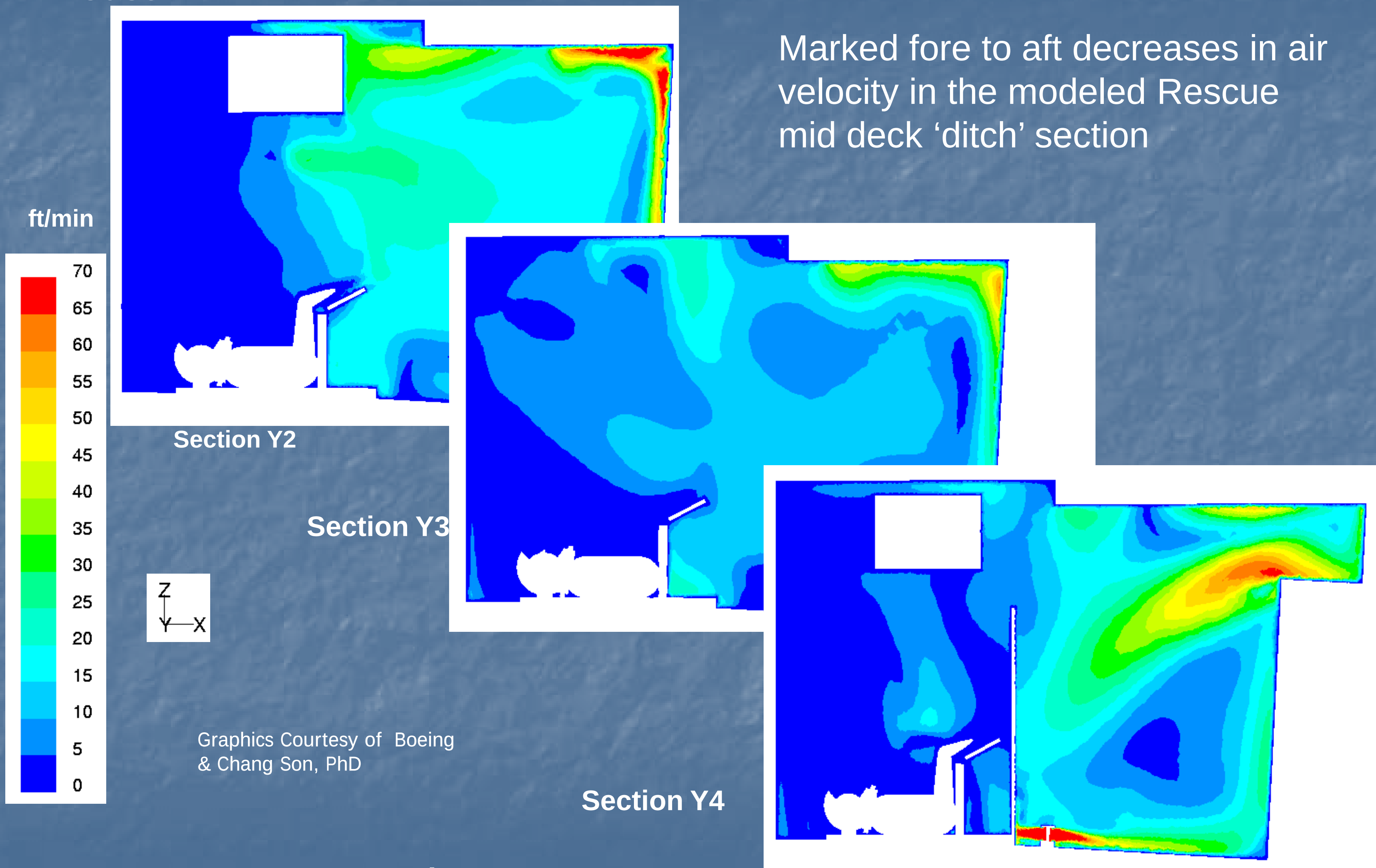
WCS based on nominal waste generation rate 7 crew, can support ~ 17 days

Graphics Courtesy of NASA

Air Velocity magnitude distributions at Y-sections

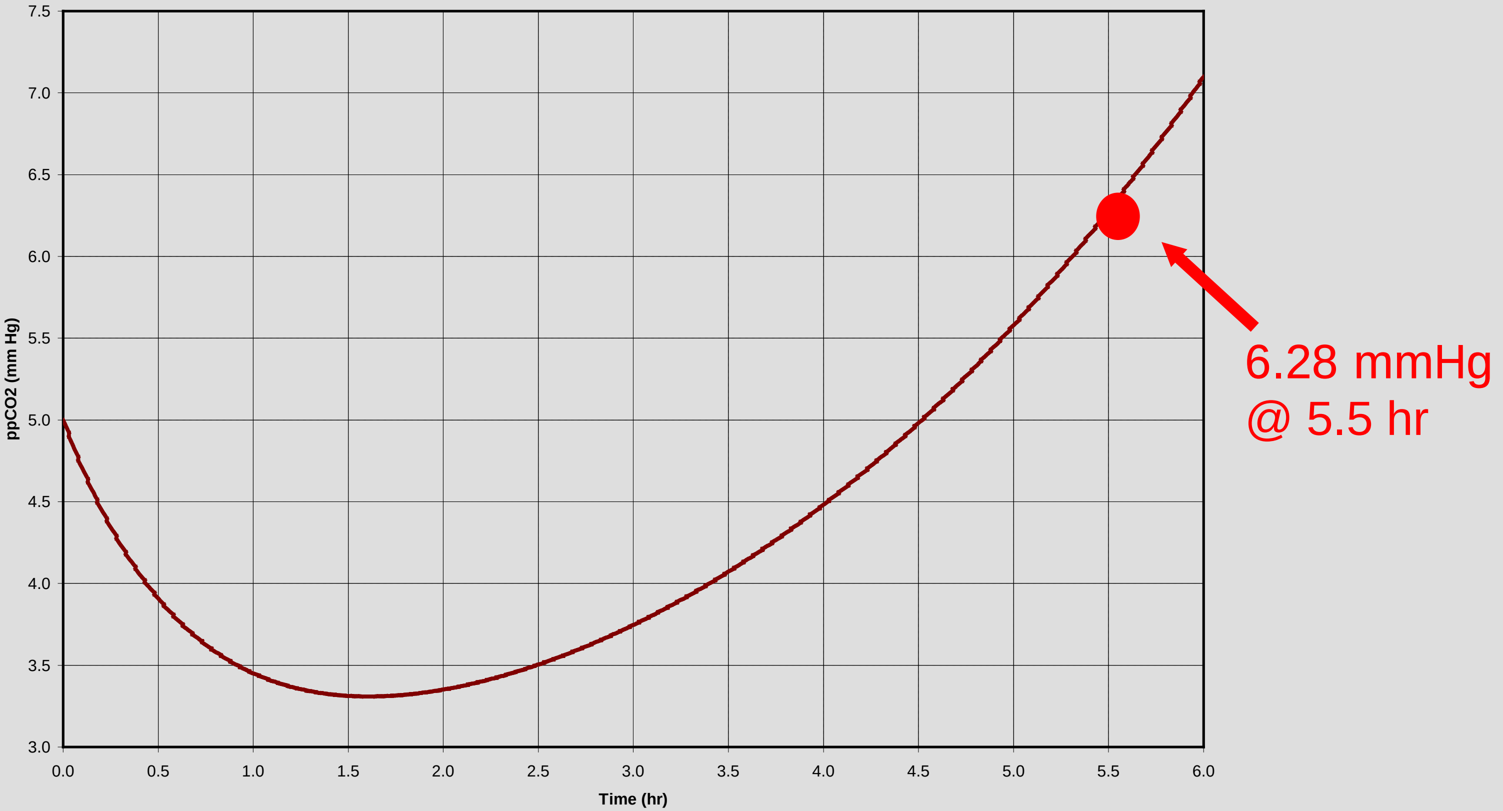
Case 1

Marked fore to aft decreases in air velocity in the modeled Rescue mid deck ‘ditch’ section



Graphics Courtesy of Boeing
& Chang Son, PhD

Forecast volume-averaged ppCO2 of Middeck, 11 persons, Shuttle re-entry, lumped-parameter model



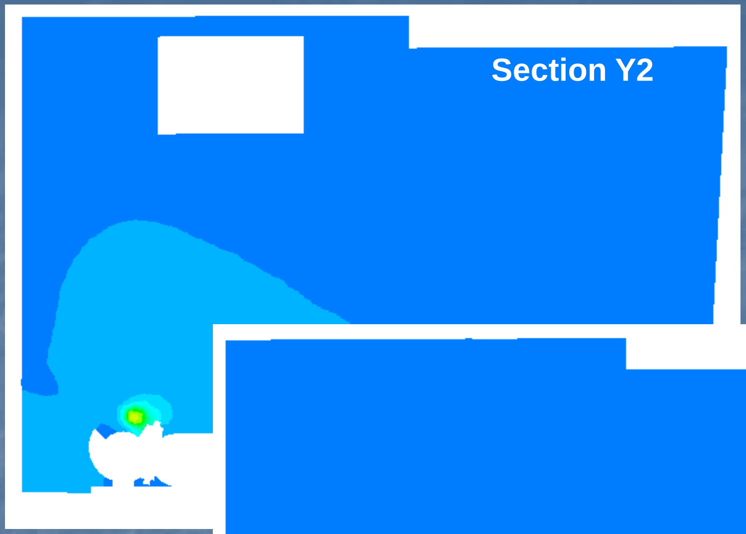
A volume-averaged ppCO2 is to 6.28 mmHg.

What is the relationship of this single point average to the inspired micro-environment of the crewmember?

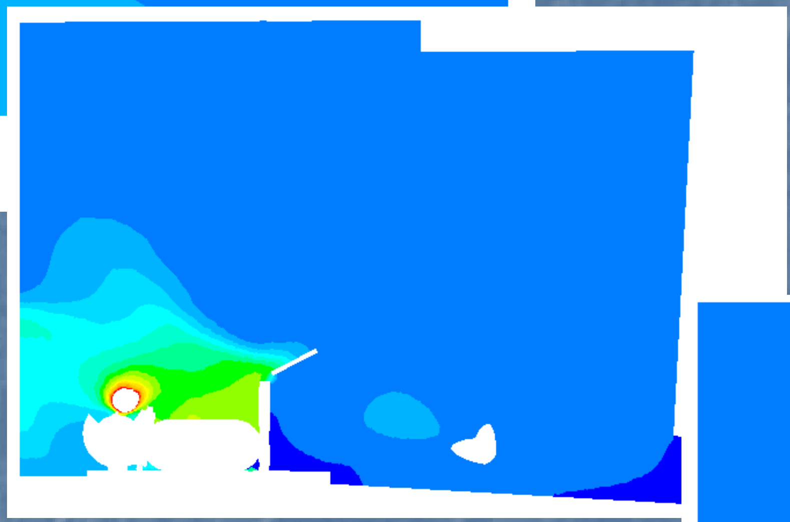
Graphics Courtesy of Boeing
& Chang Son, PhD

Graphics Courtesy of Boeing
& Chang Son, PhD

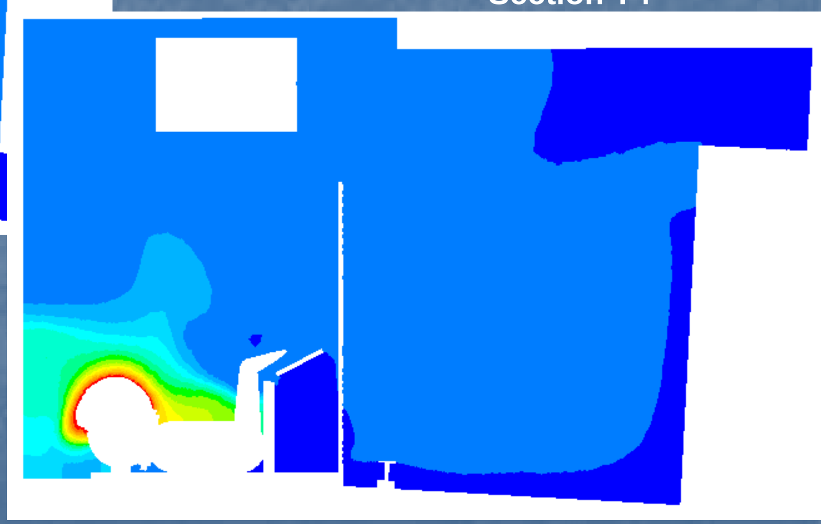
Case 1: $ppCO_2$ at Y-sections (5.5 hours)



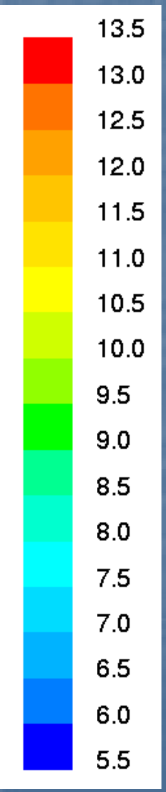
Off-scale (>13.5) ppCO2 values at face are shown in white



CFD model of CO2 shows discrepancy between crew breathing volume and general mid deck levels of CO2

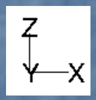


ppCO2, mmHg

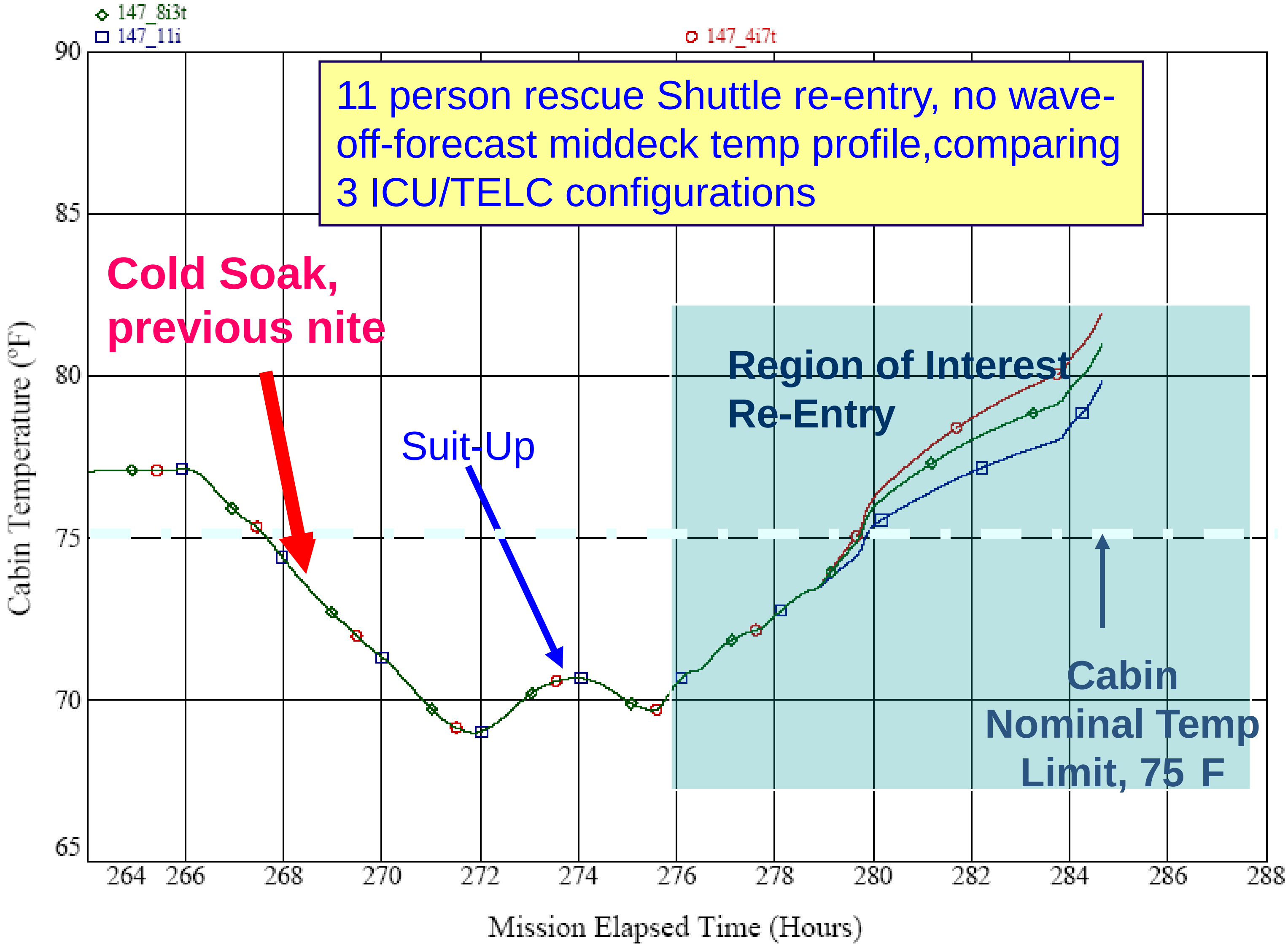


Upper scale >=13.5

Lower scale <= **5.5**



Graphics Courtesy of Boeing & Chang Son, PhD



Nominal Entry Congifuration, 14.7 psia (TD=283.73)

DTO-664 illustrates temperature spreads in Shuttle crew cabin

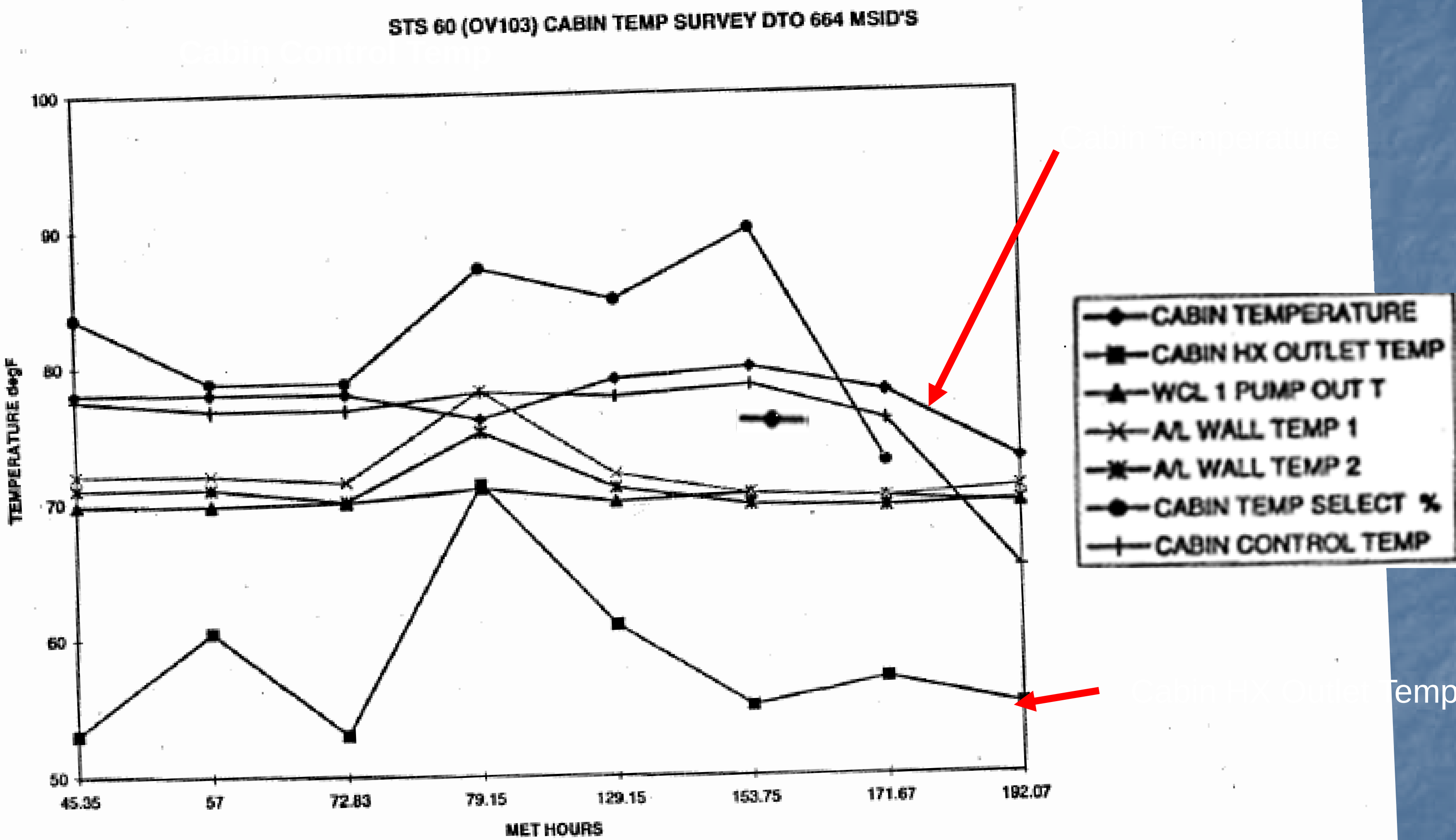
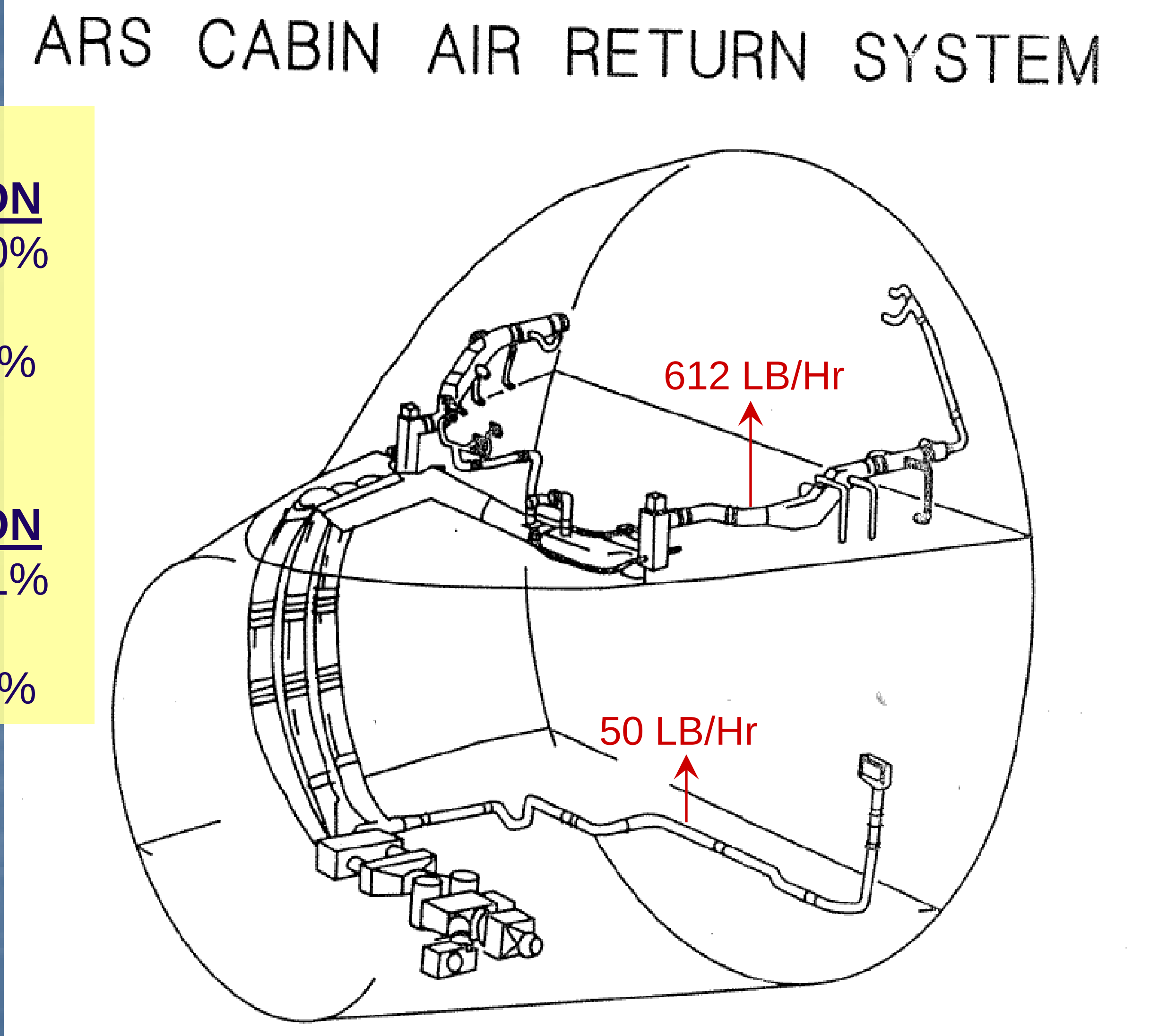


FIGURE 13. STS 60 ORBITER ARS TEMPERATURE MEASUREMENTS

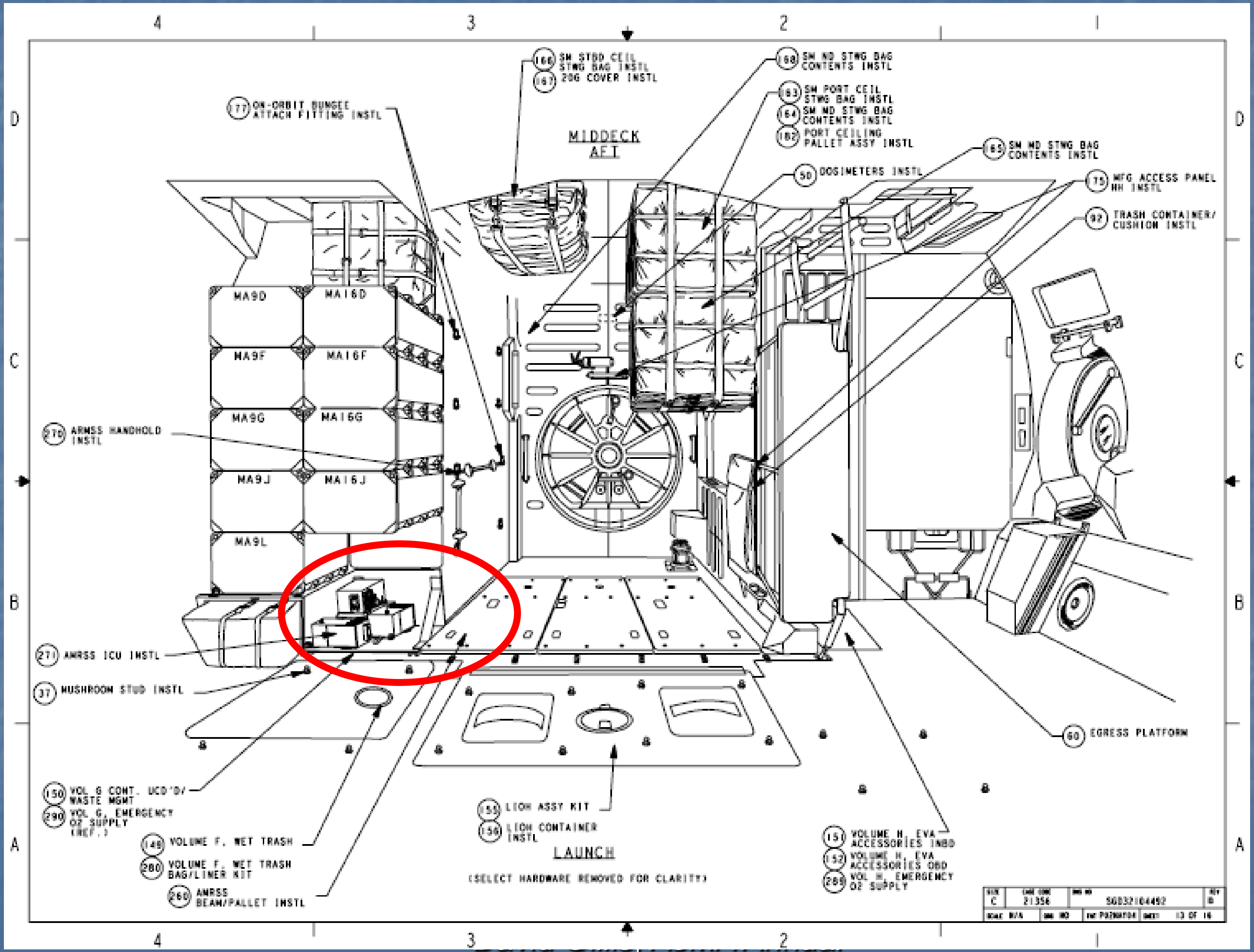
Shuttle Air Revitalization System
Cabin Air Return System

SUPPLY DISTRIBUTION
Flight Deck 50%
Middeck 41%
ECLSS Bay 9%

AIR RETURN DISTRIBUTION
Flight Deck 91%
Middeck 3%
ECLSS Bay 6%



Three ICUs stacked under Mid-Deck Lockers



Follow-on Analysis – Middeck

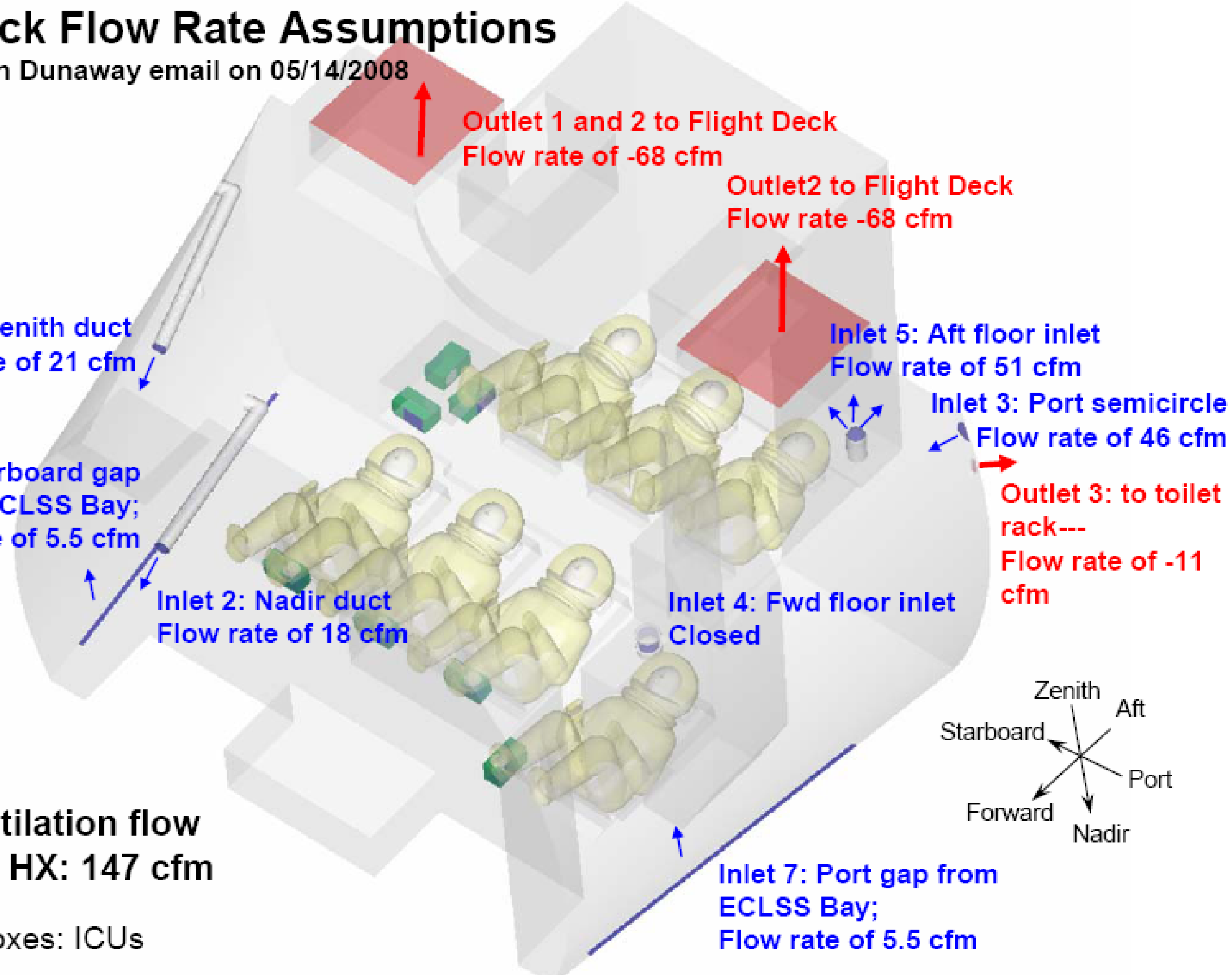
STS-326 Middeck crew core temperatures

	Core Temperature for TD-1.5		Core Temperature for TD-1.0	
	@ TD	@ Egress	@ TD	@Egress
0 Orb Waveoff	99.0	99.7	98.8	99.5
1 Orb Waveoff	99.7	100.4	99.5	100.3
2 Orb Waveoff	100.4	101.1	100.4	101.1

**Results did not take reduced middeck flow bulk analysis into account.

Middeck Flow Rate Assumptions

from Brian Dunaway email on 05/14/2008



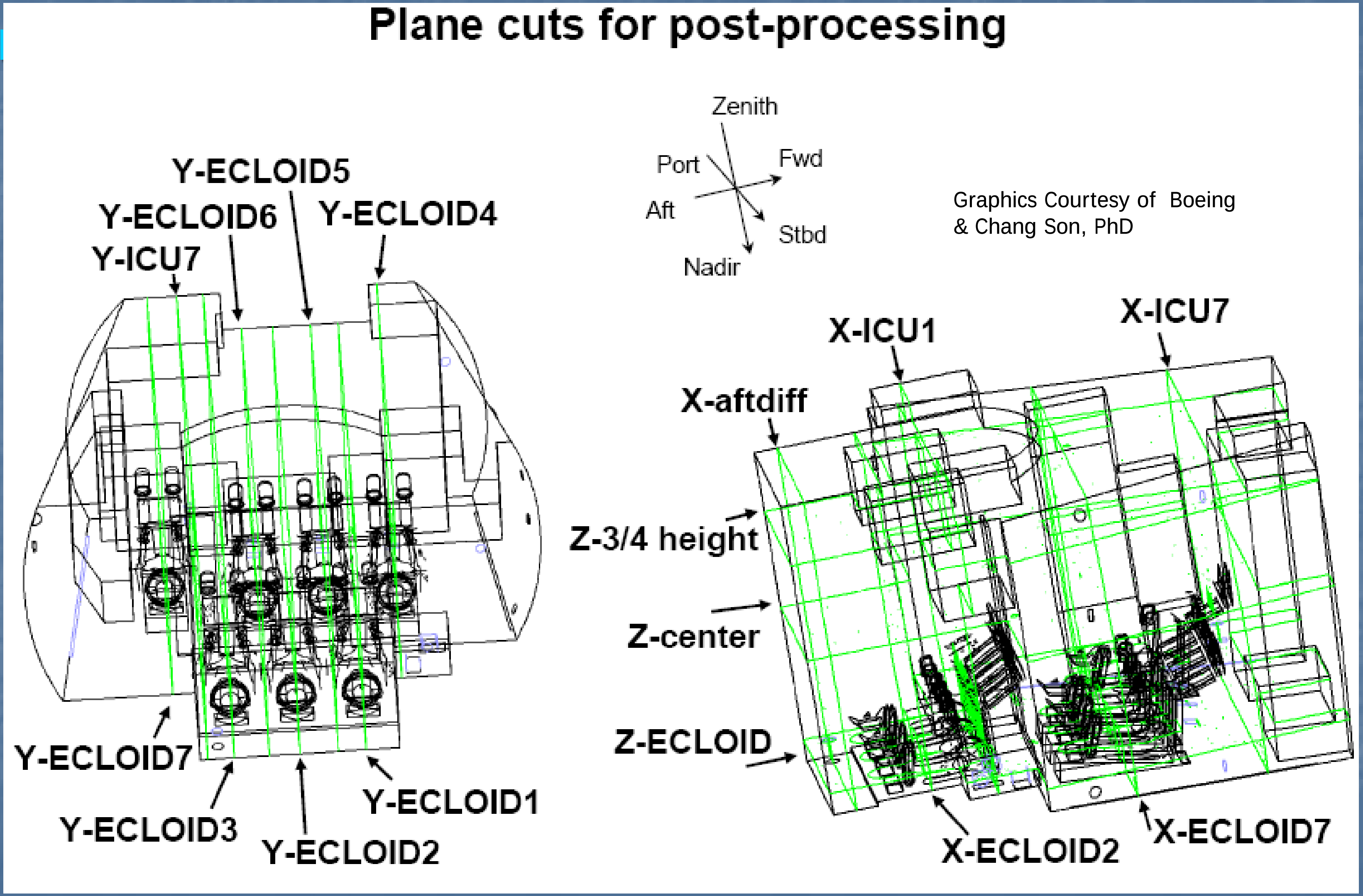
Total ventilation flow rate from HX: 147 cfm

Green boxes: ICUs

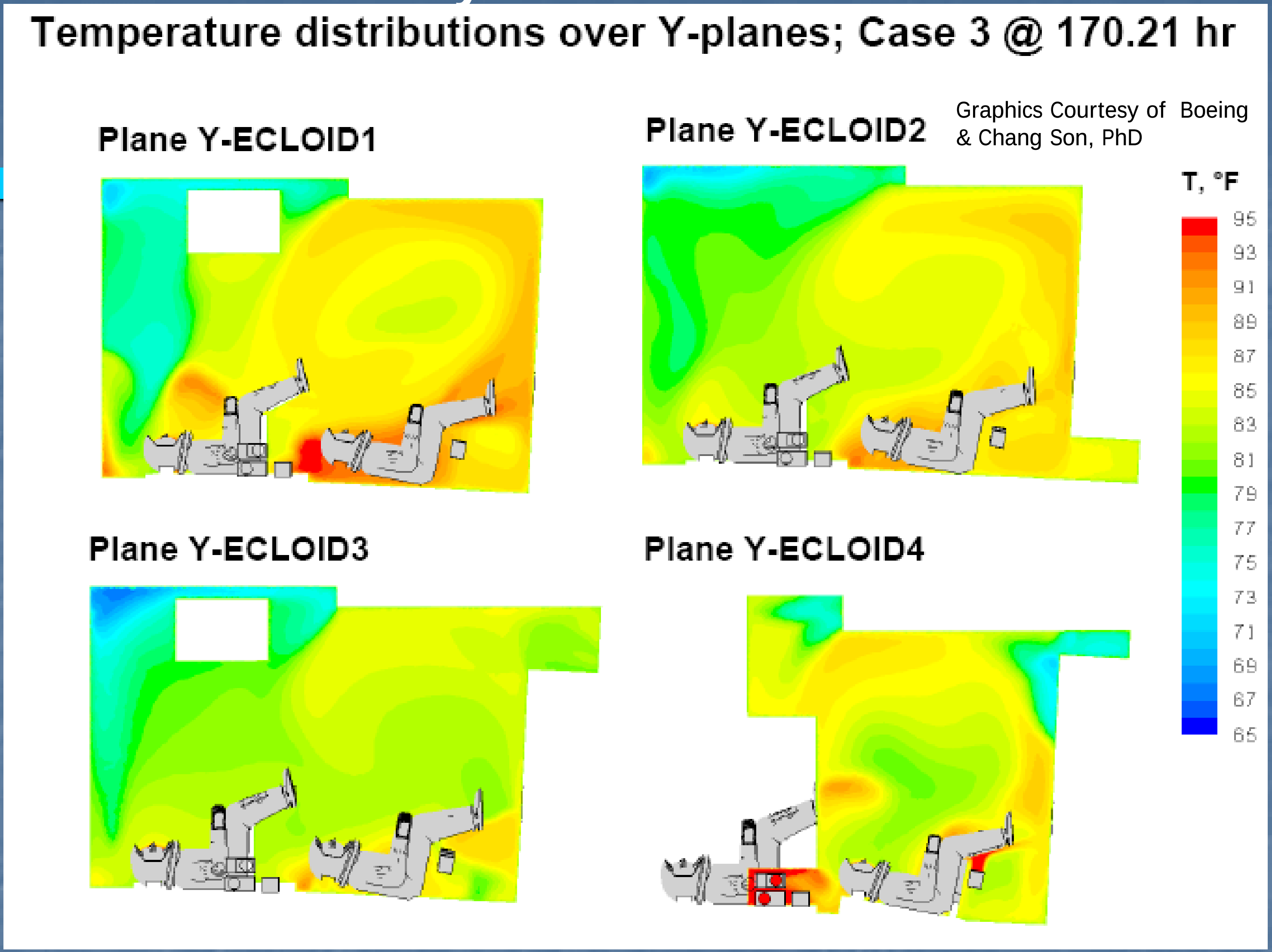
Additionally to ventilation from HX shown in the Figure, seven ICU inlets/outlets with 45 cfm each are introduced into the model (+315 cfm and -315 cfm total)

CFD by Boeing

Follow-on Analysis – Middeck CFD

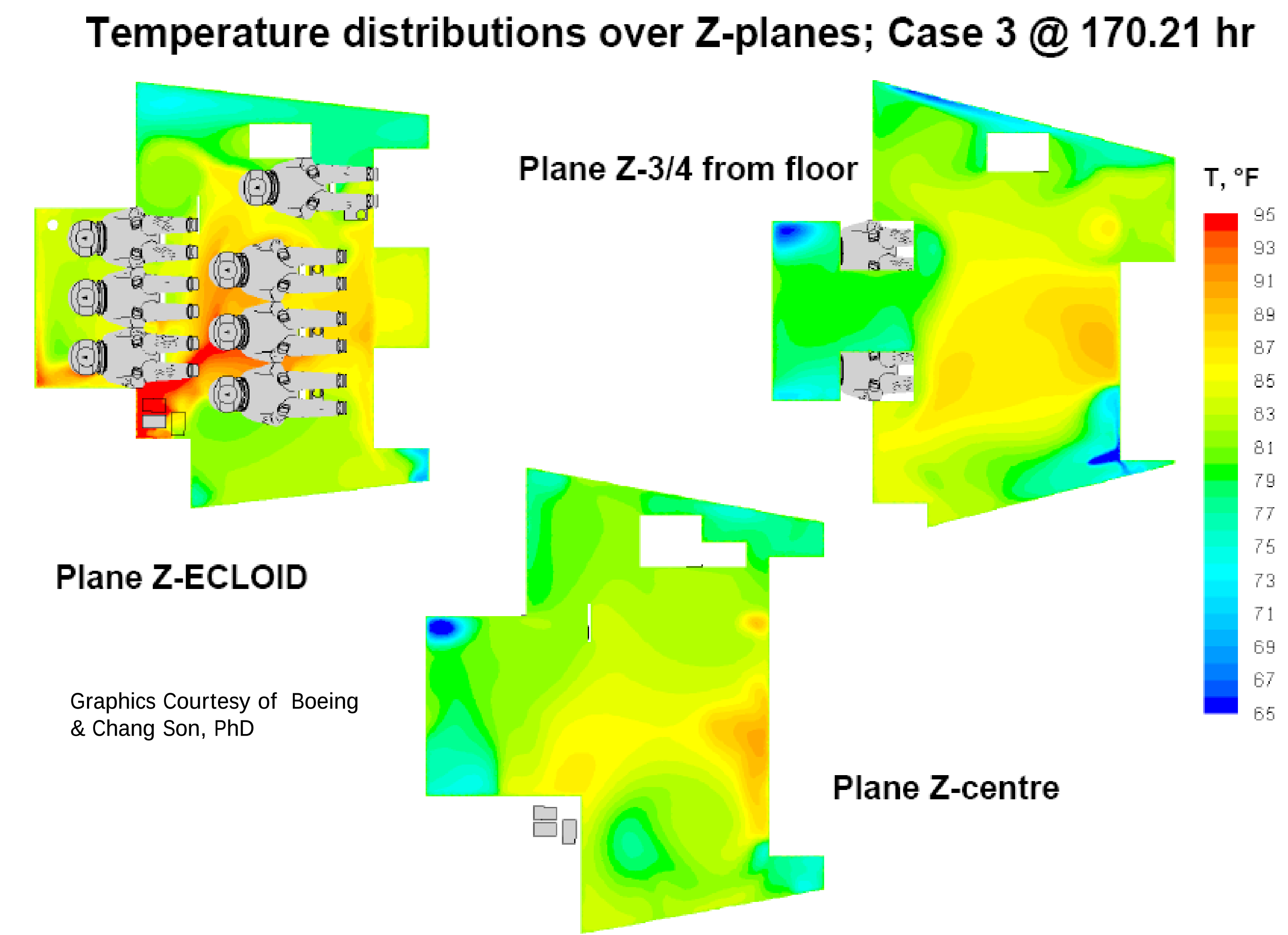


Follow-on Analysis – Middeck CFD On-Orbit

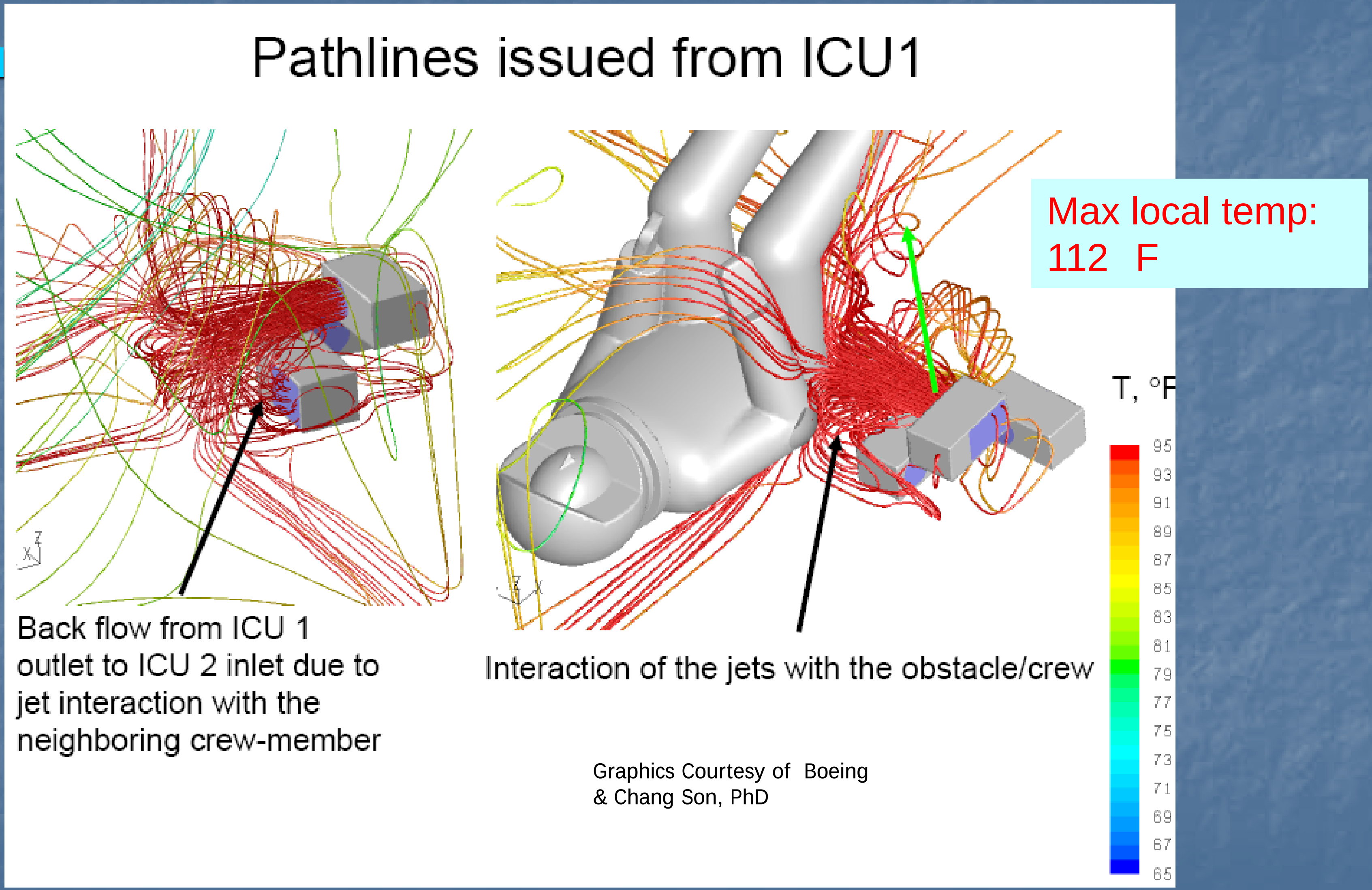


Note: Red is temp at or above 95 F, Peak temp = 112 F

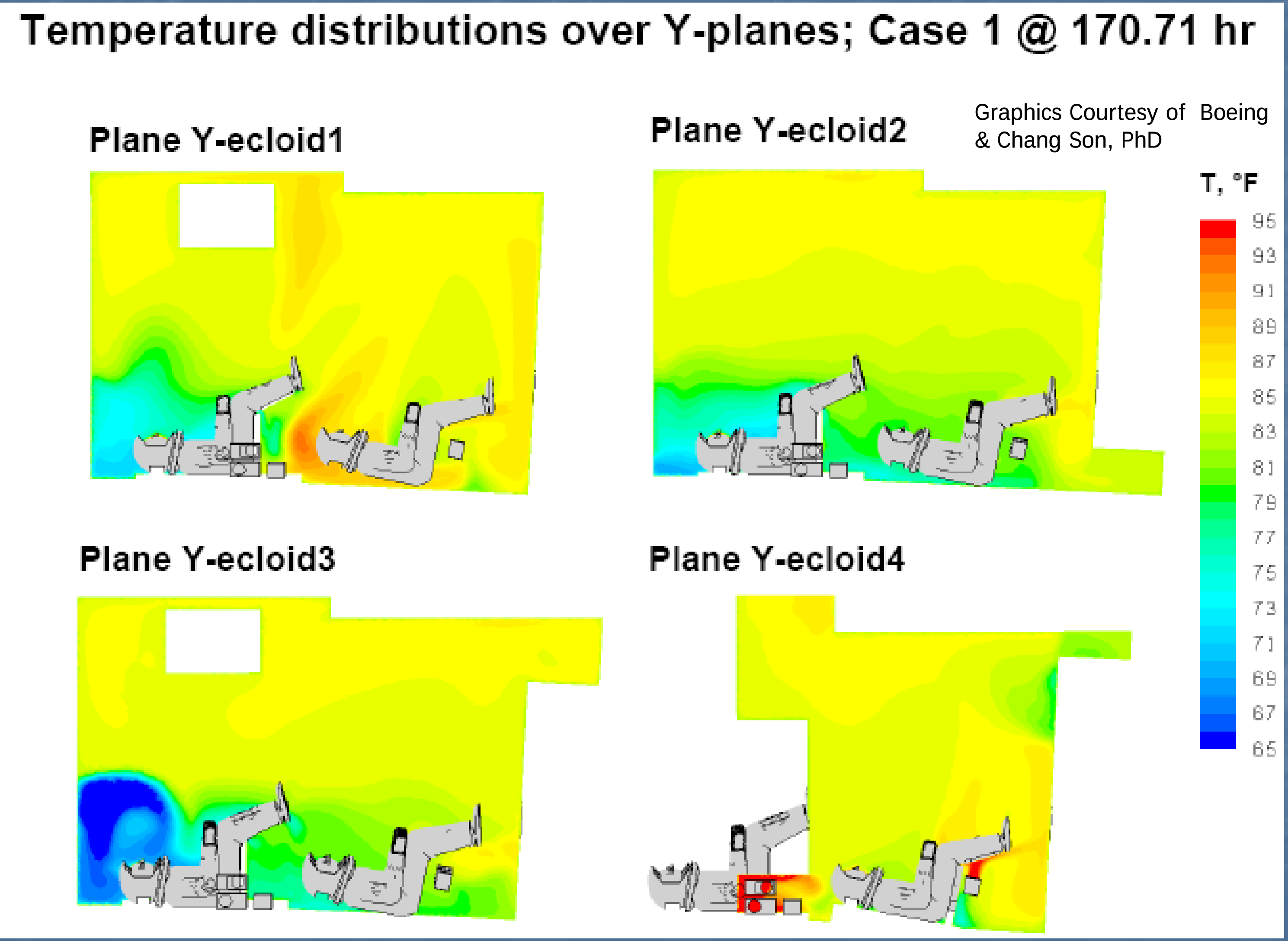
Follow-on Analysis – Middeck CFD



Follow-on Analysis – Middeck CFD



Follow-on Analysis – Middeck CFD



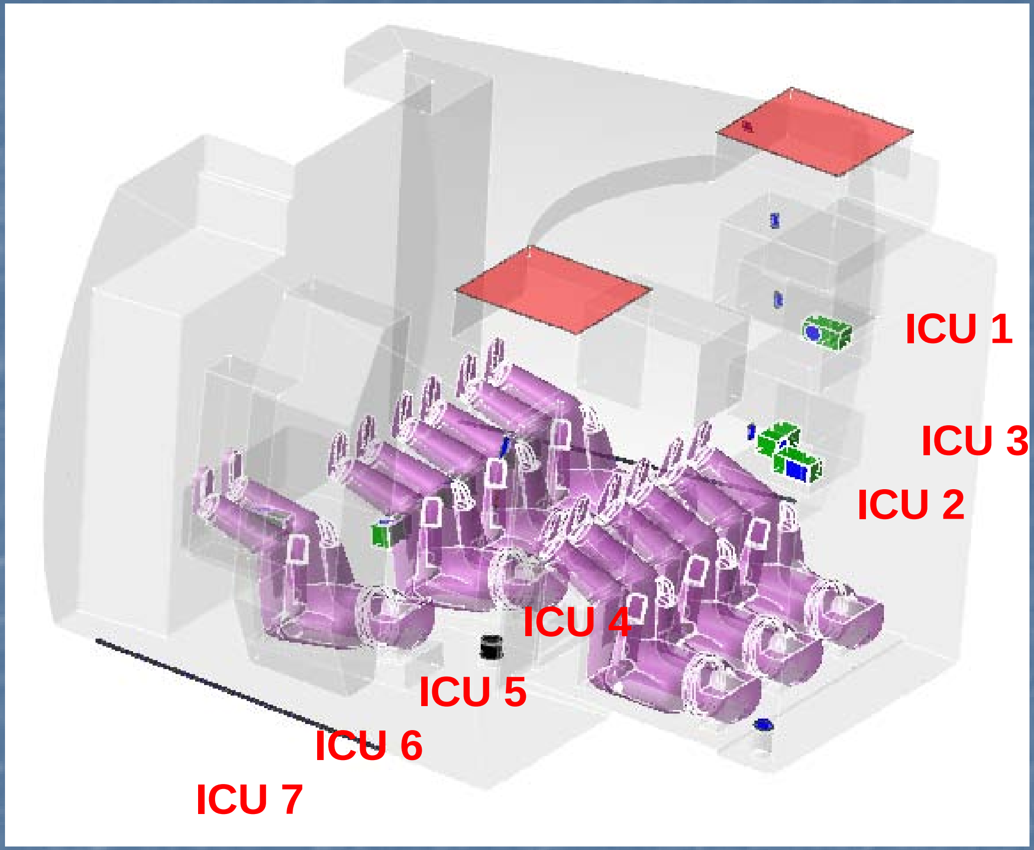
Geometry model for Middeck

Green: ICU wall

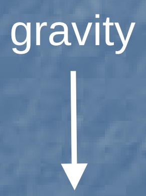
Purple: ECLSS AndrOID (ECLOID)

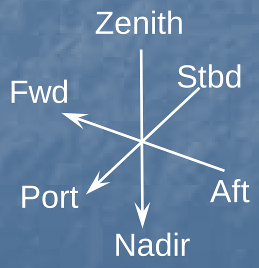
Blue: Inlets to Middeck Cabin

Red: Outlets from Middeck Cabin

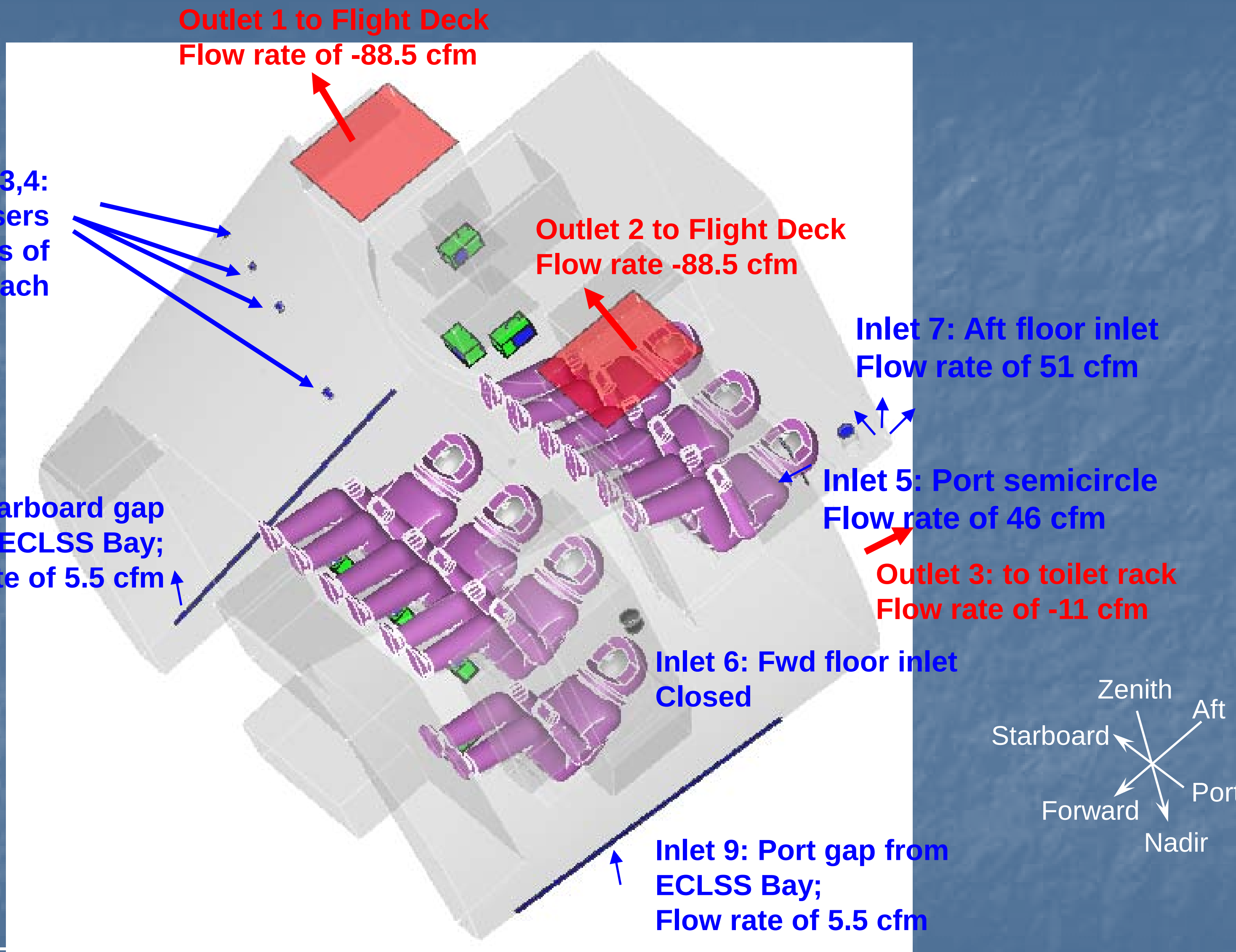


Graphics Courtesy of Boeing & Chang Son, PhD





Middeck Flow Rate and Flow Domain Assumptions



Total ventilation flow rate from HX: 177 cfm

Green boxes: seven

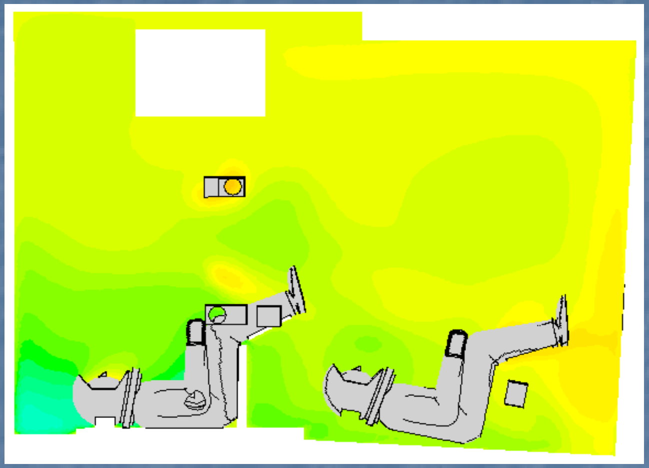
Additionally to ventilation from HX shown in the Figure, seven ICU inlets/outlets with 45 cfm each are introduced into the model (+315 cfm and -315 cfm total)

Graphics Courtesy of Boeing & Chang Son, PhD

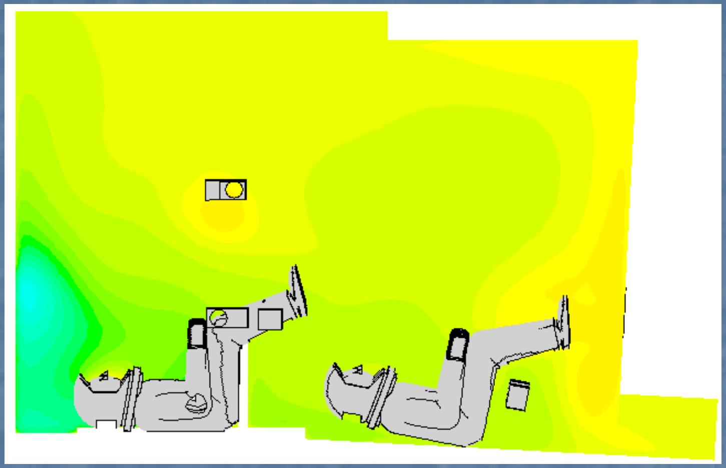
Post –mitigation CFD model of Mid Deck

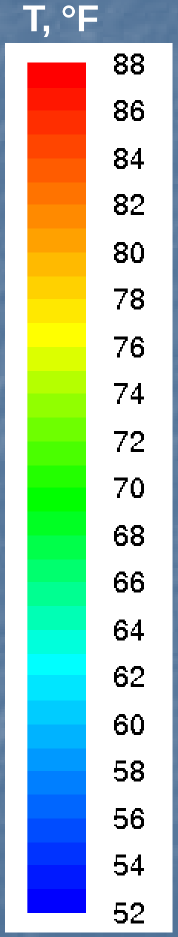
Temperature profile over Y-planes; Case 1 @ 167.55 hr

Plane Y-ECLOID1

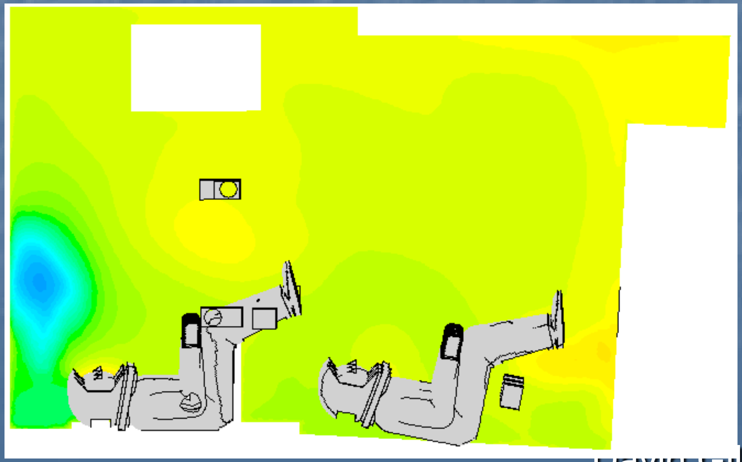


Plane Y-ECLOID2





Plane Y-ECLOID3

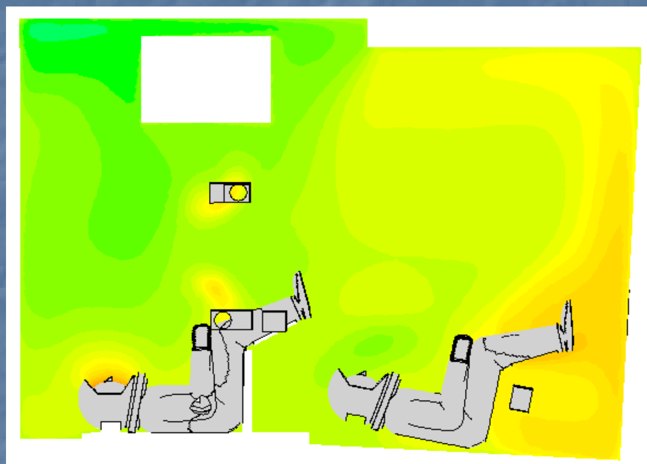


Plane Y-ECLOID4

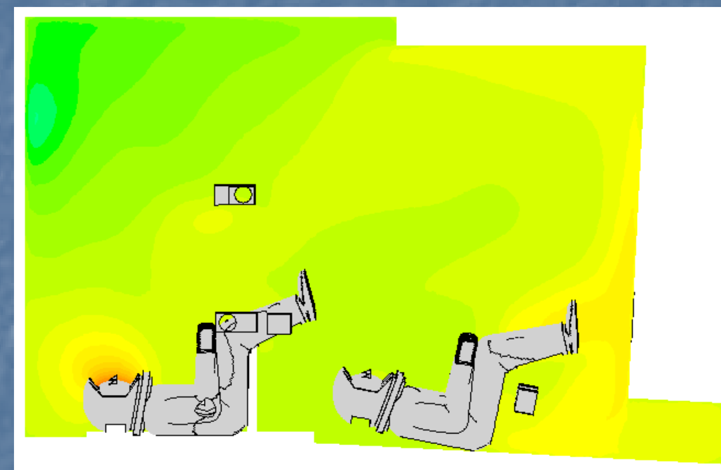
Post –mitigation CFD model of Mid Deck

Temperature profile over Y-planes; Case 2 @ 167.05 hr

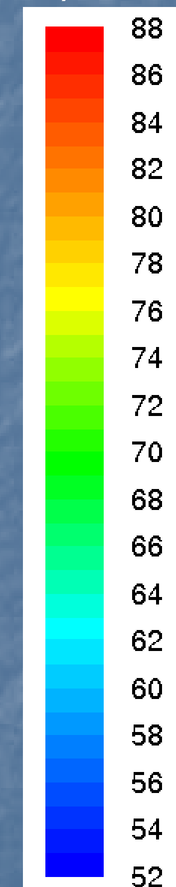
Plane Y-ECLOID1



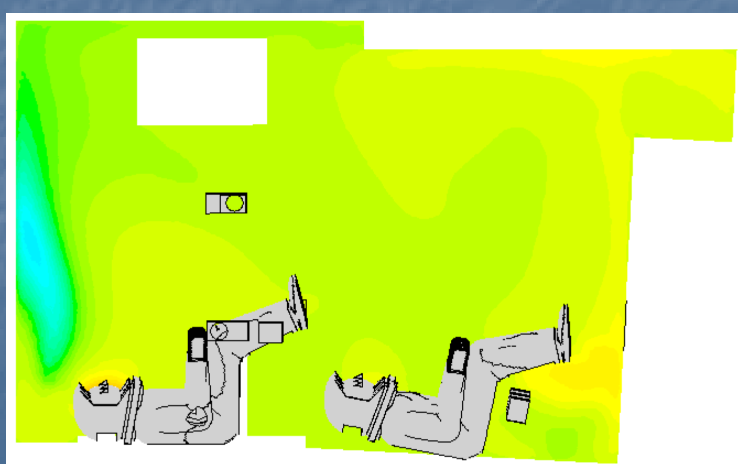
Plane Y-ECLOID2



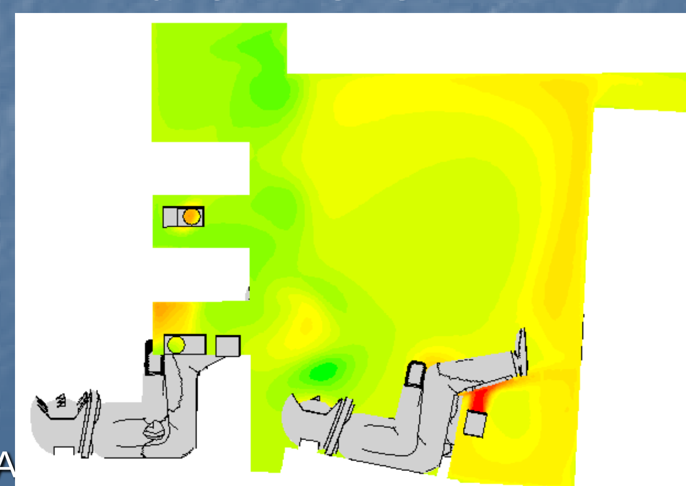
T, °F



Plane Y-ECLOID3



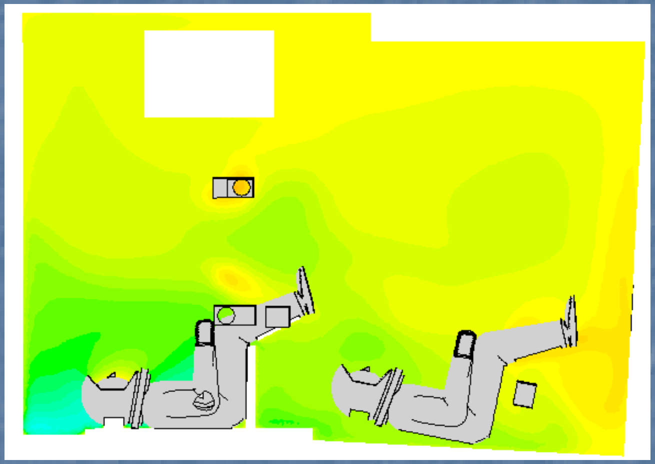
Plane Y-ECLOID4



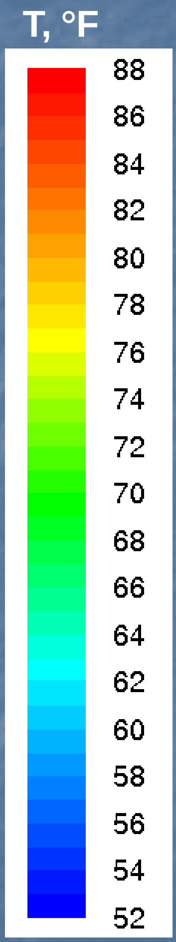
Post –mitigation CFD model of Mid Deck

Temperature profile over Y-planes; Case 3 @ 168.05 hr

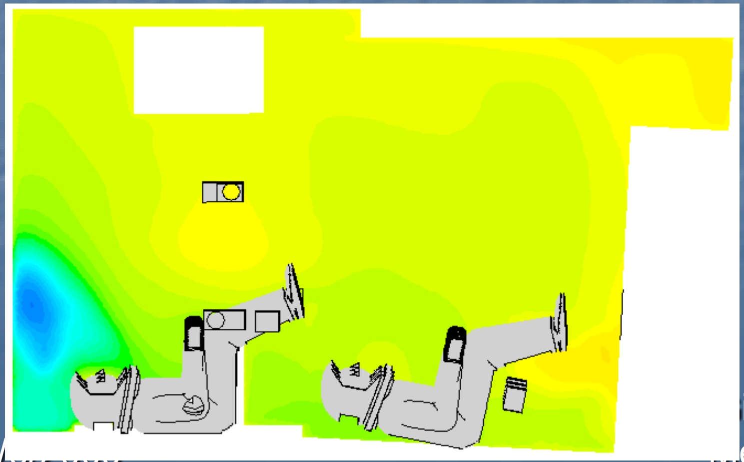
Plane Y-ECLOID1



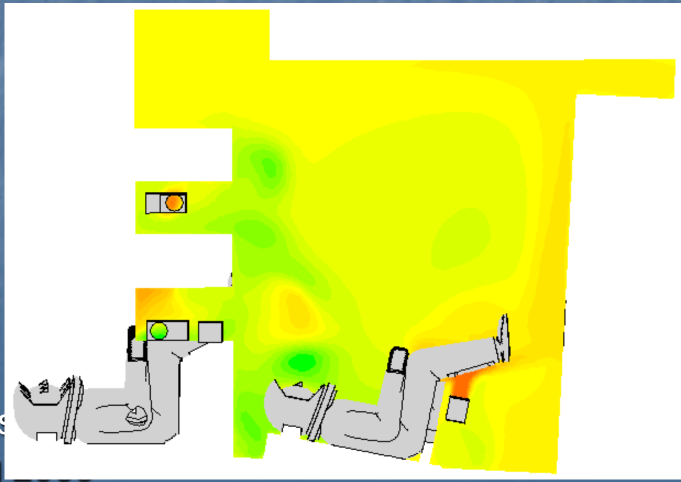
Plane Y-ECLOID2



Plane Y-ECLOID3



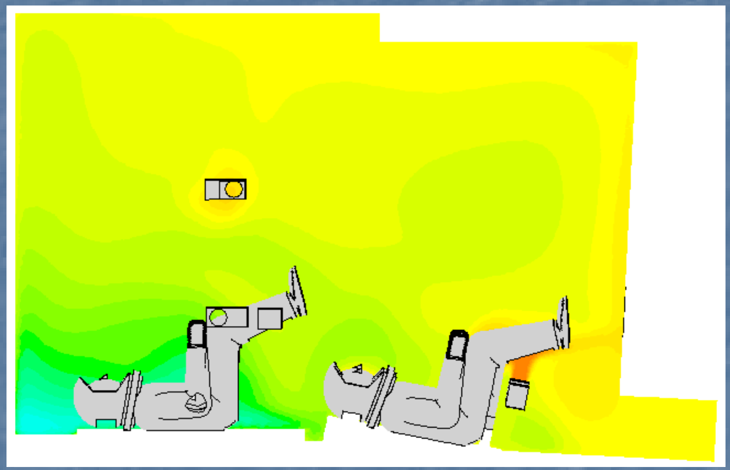
Plane Y-ECLOID4



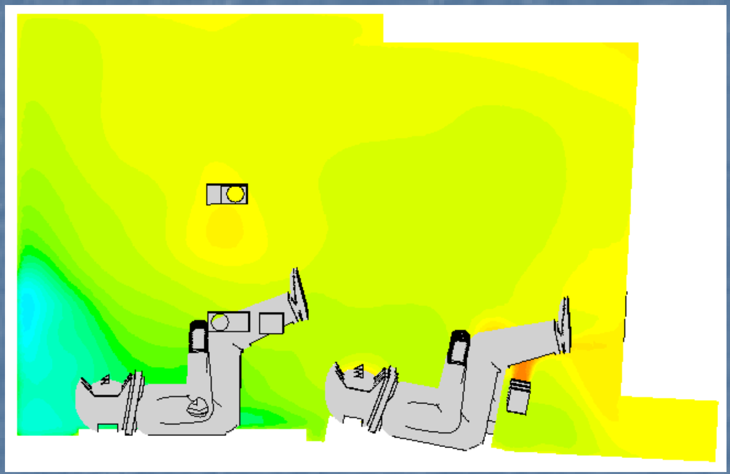
Post –mitigation CFD model of Mid Deck

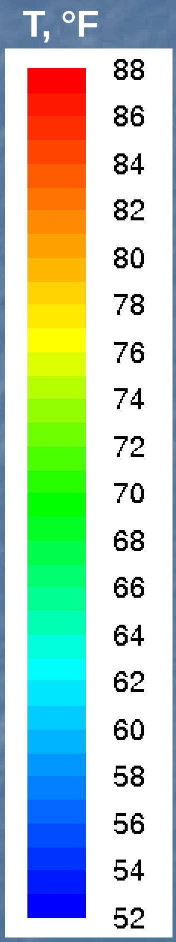
Temperature profile over Y-planes; Case 3 @ 168.05 hr

Plane Y-ECLOID5

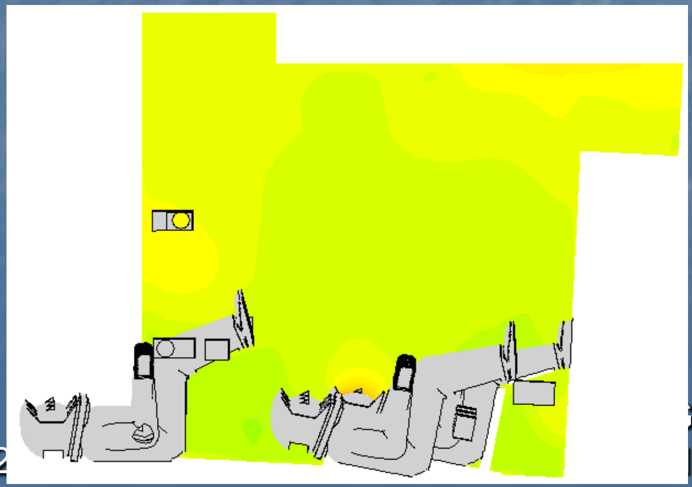


Plane Y-ECLOID6

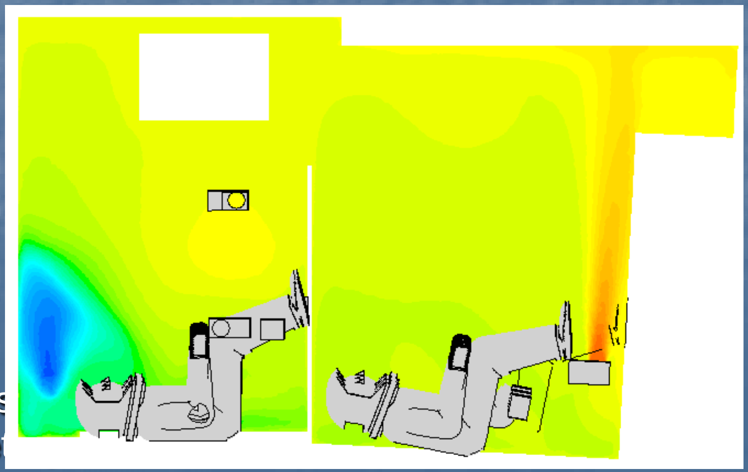




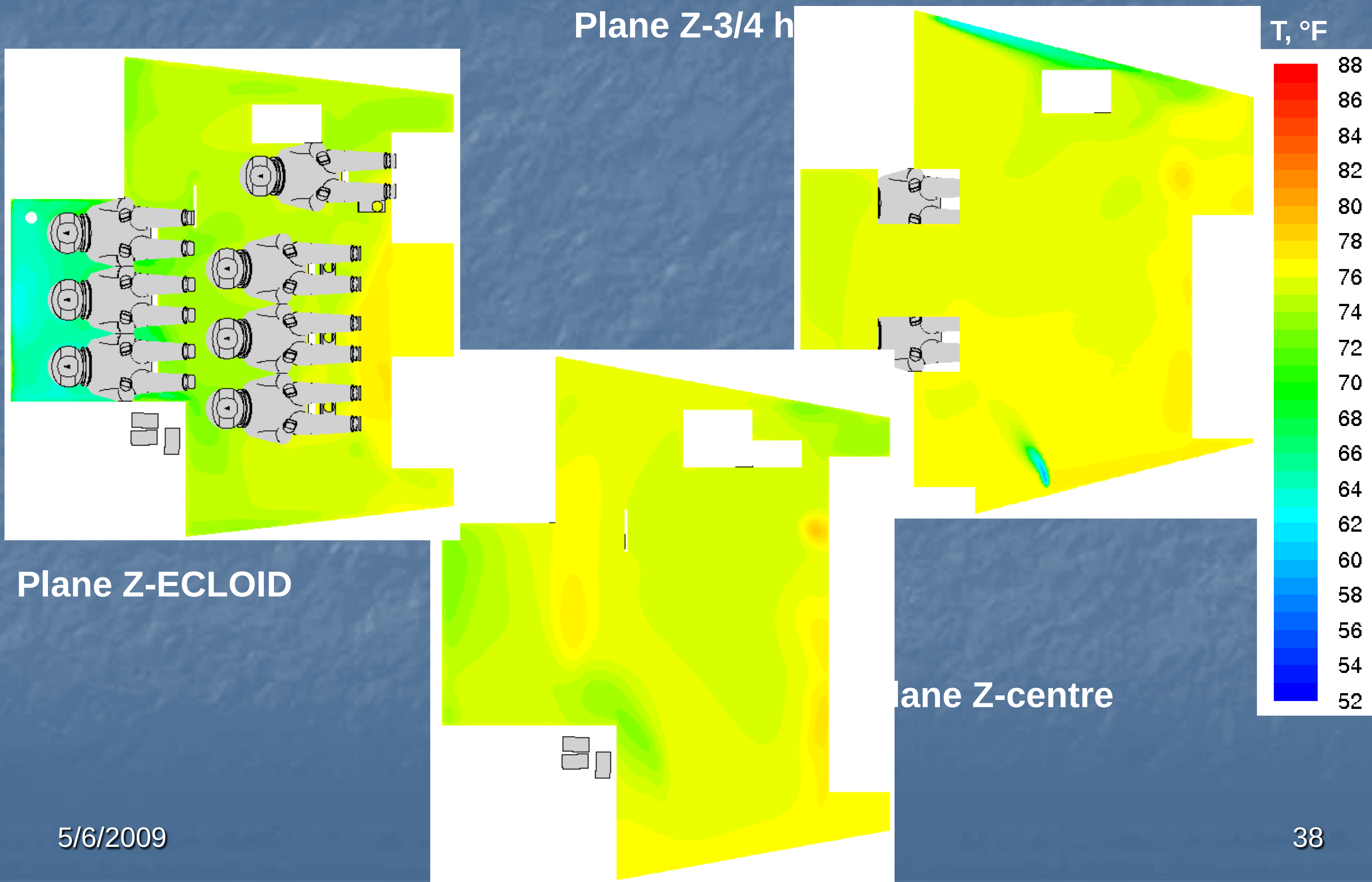
Plane Y-ECLOID7



Plane Y-ICU7



Temperature distributions over Z-planes; Case 3 @ 168.05 hr



Six Basic Environmental Variable That Affect Human Response to a Thermal Environment

1. Air Temperature
2. Radiant Temperature
3. Humidity
4. Air Movement
5. Human Metabolic Heat Generation
6. Human Clothing Being Worn

These six factors define human thermal environments.

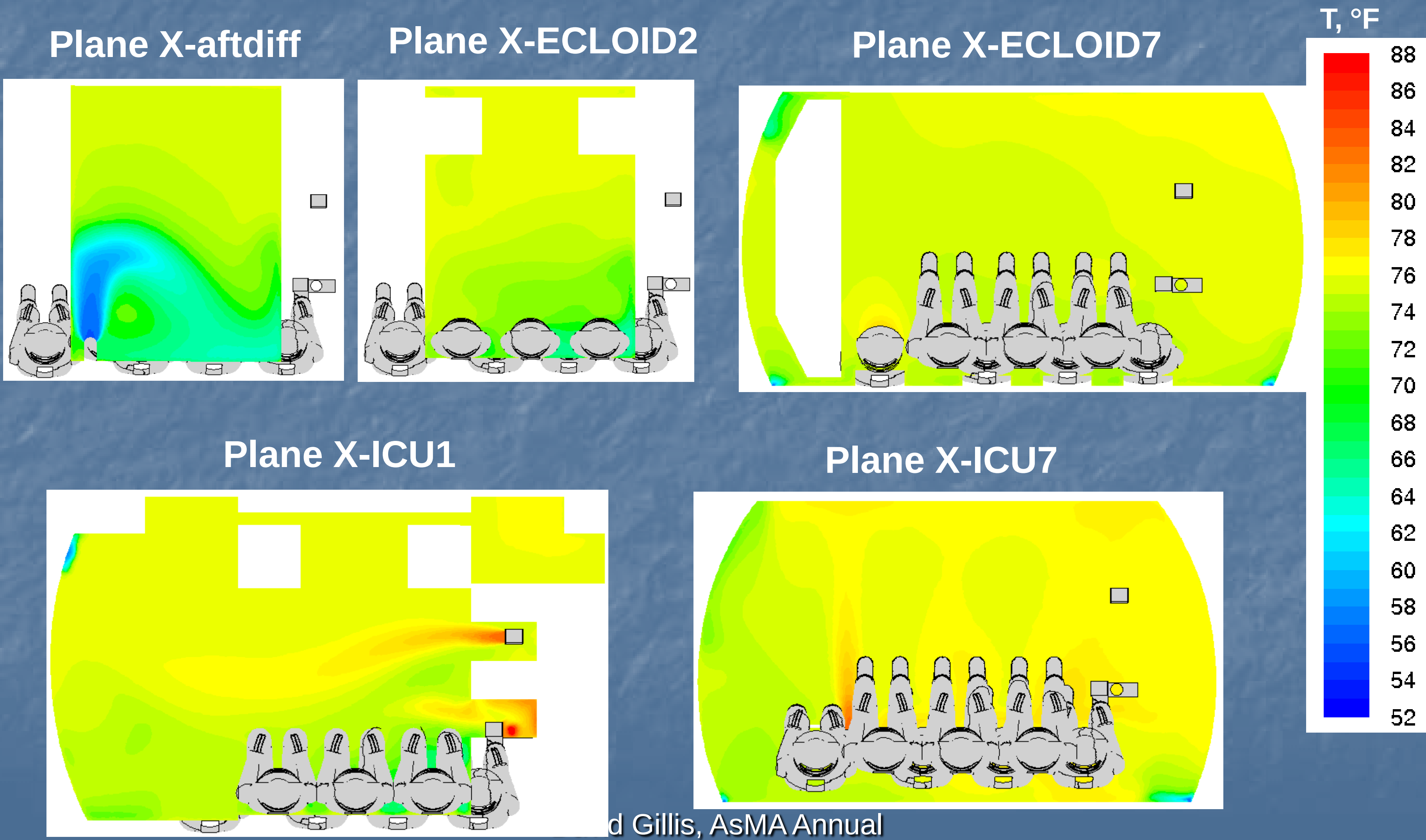
Defining environmental limits in terms of only air temperature are insufficient in many situations and ignores, or implies assumptions regarding the other 5 environmental variables.

Radiation temperatures may greatly effect an individual environment.

Assumptions regarding each of the six basic variables need to be explicitly stated rather than implied but not specified.

Post –mitigation CFD model of Mid Deck

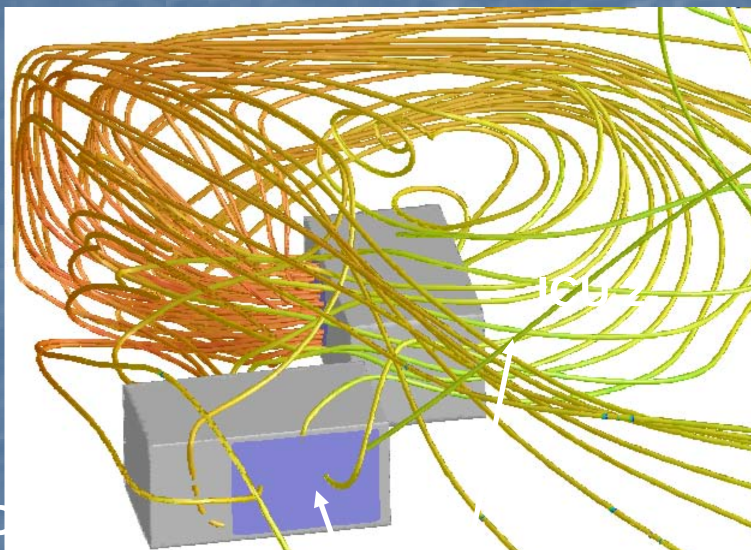
Temperature profile over X-planes; Case 1 @ 167.55 hr



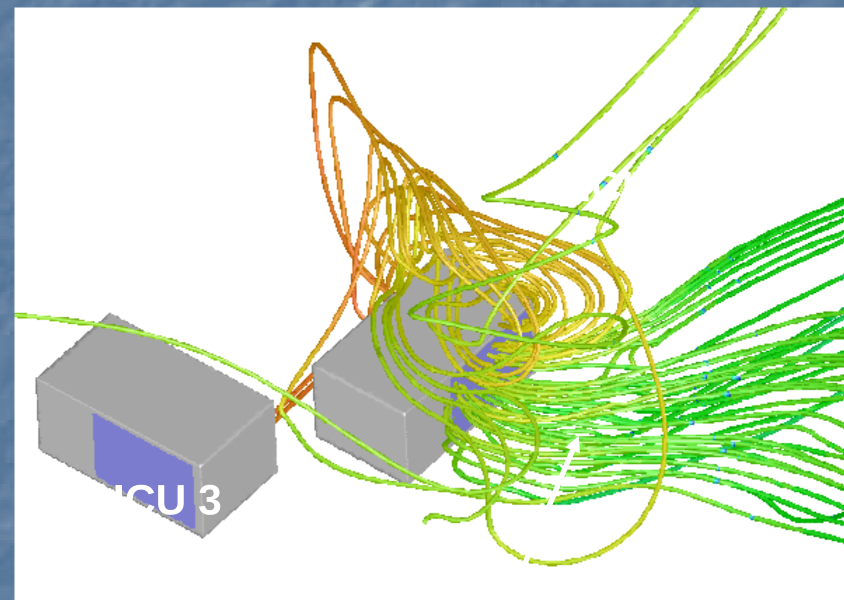
Post –mitigation CFD model of Mid Deck

Pathlines colored by air temperature; Case 1 @ 167.55 hr

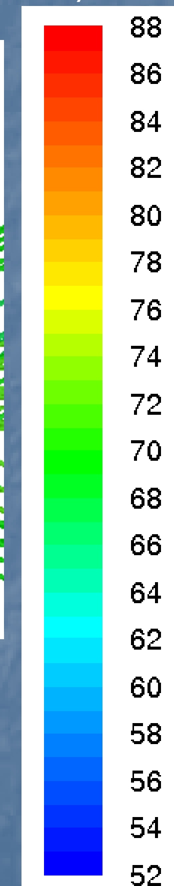
Pathlines from ICU 2 outlet



Pathlines to ICU 2 inlet



T, °F



Weak back flows from ICU2 outlet to ICU2 and ICU3 inlets

Most of the air is from outside, few pathlines come from ICU2 and ICU3 outlets

Mitigtions for Safety- Procedures

- Full cold soak night prior to deorbit
- Orbital Wave-off for wether not supported, full-day wave-off with suit doffing
- Delayed, staggered suit-up for de-orbit
- Modify deck stowage to reduce interference with air flow
- Early securing of avionics post-landing (to reduce cabin thermal load prior to hatch opening
- Early hatch opening and increased ground cooling with lower air temperature
- Re-entry with visors open

STS-125

STS-125 is currently scheduled to launch 12 May 2009

Photo courtesy of NASA

STS-400

STS-400 will be prepared to launch within 7 days of Rescue requirement notice

Photo courtesy of NASA

- STS-400 is also on the Pad, prepared to launch on no later than
- 7 days after notificaiton of Rescue Mission Requirement

Mitigtions for Safety- Engineering

- Remove Duffy ducts, open diffusers
- Use TELCs on for Commander & Pilot
- Modify location of aft starboard ICUs, eliminating the X3 Stack and eliminating ICU exhaust air directed onto astronaut
- Improved engineering data of ICU performance
- Improved ACES heat rejection understanding
- Use 600 BTU in Mid Deck temperature modeling and core temperature predictions
- Verify adequacy of Mid Deck temperature control using CFD models in addition to lumped parameter models

Mitigtions for Safety- Core Temperature Limits

- Require Flight Deck CDR & Pilot core temperature predictions not to exceed normal (approximately 98.6 degrees F) during re-entry for a high level of cognitive performance

- Require Mid Deck crew member core temperatures not exceed 99.9 degrees F during re-entry to protect for cognitive and physiological ability to execute a Mode VIII escape should that become necessary