

	Presenter: John Hunt
	Organization/Date: SSP / 10-16-07

Advanced Master Events Controller

MEC System Overview

Presenter:

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Organization/Date:

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- **The master events controller (MEC) validates and executes general purpose computer (GPC) commands for ignition and separation functions during pre-launch, lift-off, SRB/ET separation**
- **The MEC also controls power to the SRB, range safety, attitude thrust vector control systems**
- **The two MECs each contain two independent cores providing quad redundancy to the system**
 - **Each core is designed such that a failure in one core cannot propagate to the other**
 - **Each core is capable of processing and executing data independently**

MEC System Overview

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- There are three types of MECs, two of which are very similar in design
 - The original MECs, though flight worthy, have not flown since 2002
 - The redesigned MECs, identified as enhanced MECs (EMECs) have flown since 1992
 - Only 2 EMECs were built and delivered
 - The EMEC design was subsequently updated in the form of the advanced MEC (AMEC), but remained very similar to the EMEC
 - 8 AMECs remain available
- OV-103 currently has an EMEC installed in slot 1 and an AMEC in slot 2 (ref figure - OV-103 configuration)

MEC System Overview

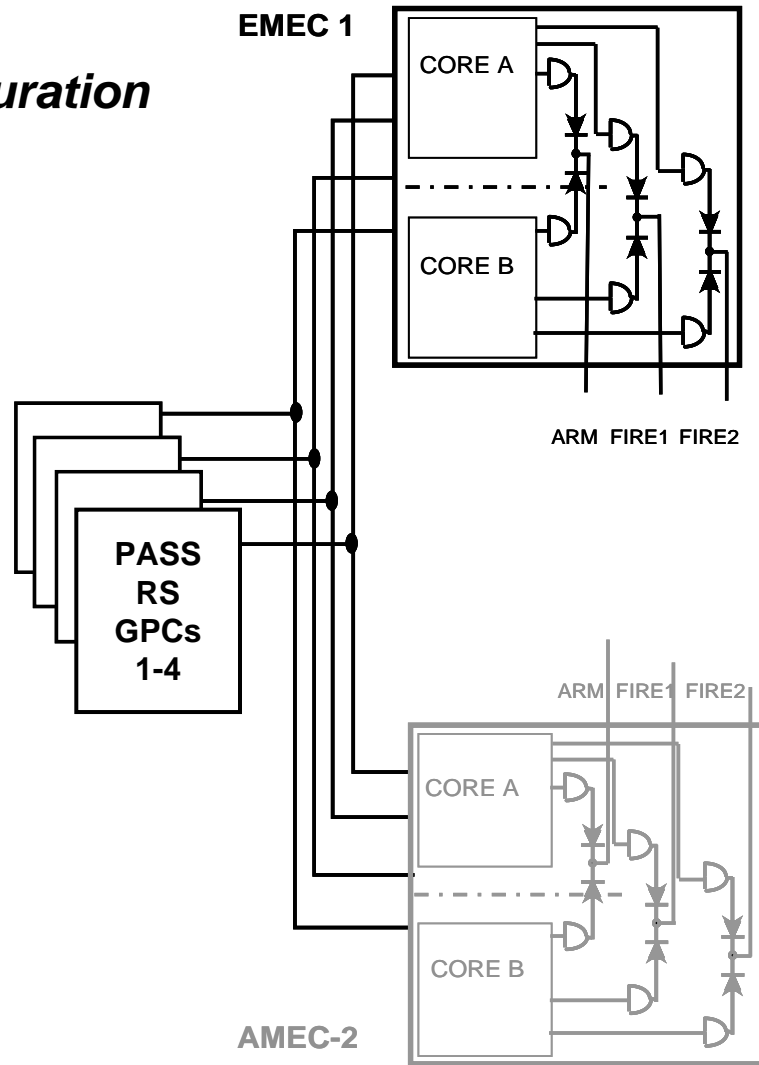
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OV-103 Configuration



<h1>Issues</h1>	Presenter: John Hunt
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- **Recently, three issues were observed relative to the MEC subsystem:**
 1. **During testing at JSC Shuttle Avionics Integration Lab (SAIL), AMEC s/n 0004 issued select uncommanded outputs during flight software testing**
 2. **Also during SAIL testing, spurious outputs at power-down were witnessed on AMECs 0004 and 0006**
 3. **During rework, EMEC and AMEC circuit modules (cards) were found translated upward, away from connectors**

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Issue 1. Uncommanded Outputs

1. Uncommanded Outputs

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Observations:

- During SAIL testing, AMEC s/n 0004 issued uncommanded outputs
 - Command outputs on pyro initiator controller (PIC) 'ARM' and 'non-critical' circuits were detected minutes after transitioning from ground test software (G9) to ascent flight ops (G1)
(ref backup - Failed Commands)
 - Observed failure mode is a 3.12 msec pulse with an amplitude equal to nominal aft main bus voltage (28 Vdc) then loss of function due to AMEC internal safing circuit.
 - Troubleshooting has confirmed that the condition is an isolated failure internal to AMEC s/n 0004

Concern:

- Effects of uncommanded MEC system outputs on Orbiter, SRB, RSS, and ground systems if comparable occurrence occurred pre-launch or during ascent

1. Uncommanded Outputs

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Background:

- AMECs s/n 0004 and 0006 completed rework at NASA Shuttle logistics depot (NSLD) for tin whisker mitigation and shipped to SAIL in July 2007 for 500 hour burn-in
- The uncommanded outputs failure was observed and led to detailed root cause identification efforts
- The AMEC positions were swapped and was isolated to AMEC 0004
 - AMEC 0006's behavior was nominal
 - AMEC 0004 core isolation determined that the condition was isolated to core B; core A was nominal
 - Voltage data, from chassis test connector, confirms failure isolated within core B 5vs1 power distribution of AMEC 0004 (ref backup - Power Distribution)
- The uncommanded outputs occurred only following transition from ground test (G9) to ascent flight ops (G1)
 - Detection was one to four minutes after the ops transition

1. Uncommanded Outputs

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Discussion:

- AMEC 0004 has been shipped to the NSLD where TT&E has commenced
- The observed condition has not been replicated to date
- The SAIL-collected data points to a failure in the power distribution circuitry which provides logic power to ARM/NCR and BITE
 - FIRE1/FIRE2 functions are isolated and independently powered
- Replication may require exposing the unit to continual command traffic as exists in G1 flight software
 - GPC commands issued to the MEC every 40 msec
- The SAIL observed failure is detectable on the vehicle and was not detected during terminal countdown demonstration test (TCDT), the only routine transition to G1 prior to countdown
 - Post-test AMEC BITE would have identified such an occurrence

1. Uncommanded Outputs

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Risk Assessment:

- **No risk for uncommanded critical outputs**
 - PIC 'ARM' is only one of three required commands to detonate a pyro (ARM – FIRE 1 – FIRE 2; in that sequence)
 - Partitioning of 'ARM' and 'FIRE' functions between separate modules with isolated power sources, prevents prematurely firing a PIC
 - Qualifier drivers (output of 'FIRE 1' powers 'FIRE 2') further prevents premature PIC firing
 - Circuit analysis determined that pulse duration is insufficient to charge a PIC to nominal value of 38 Vdc
 - PIC maximum charge 0.3 Vdc
 - Launch commit criteria (LCC) violation if uncommanded PIC voltage reaches 1.5 Vdc
- **Low risk for uncommanded non-critical outputs**
 - Non-critical power functions are set 'on' prior to software transition to G1, with no premature impact after transition
 - Worst case is SRB RSS system B power off
 - Latching circuit may engage resulting in a LCC violation
 - Loss of one of two RSS systems if unsolicited command occurs in flight

1. Uncommanded Outputs

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Acceptance Rationale for STS-120:

- Failure is isolated to AMEC 0004, core B
- Partitioning of critical commands 'ARM' and 'FIRE' prevents premature PIC firing
- Unsolicited critical ARM commands issuance is not a launch issue

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Issue 2. Spurious Output at Power Off

2. Spurious Output at Power Off	Presenter: John Hunt
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Observation:

- During SAIL testing, AMECs 0006 and 0004 issued spurious outputs at power-down
 - Outputs were approximately 10 Vdc for 3 msec
 - Failure is repeatable and likely generic in nature
 - All outputs are presumed to be affected

Concern:

- Effects of spurious MEC system outputs on Orbiter, SRB, RSS, and ground systems upon power-down of AMECs following ordnance installation

2. Spurious Output at Power Off	Presenter: John Hunt
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Background:

- As previously noted, AMECs 0004 and 0006 were shipped to SAIL in July 2007 for 500 hour burn-in
- Discovery of the condition was due, fundamentally, to the uncommanded output failure of AMEC s/n 0004 at SAIL and the addition of a high speed instrumentation system not previously utilized with the hardware
 - A high-speed, graphic recorder was installed and recorded the anomaly on both AMECs 0004 and 0006
 - Condition was repeatable at ~10 Vdc for 3 msec (ref backup - Spurious Output at Power Off Waveform)
- Similar spurious outputs were recorded in 1998 during vendor thermal qualification testing
 - Voltage “spikes” were 17 Vdc in amplitude for 200 microsec
 - Design fix implemented believed to have corrected the condition
 - Design should “clamp” all outputs within 20 microsec

2. Spurious Output at Power Off	Presenter: John Hunt
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Discussion:

- The condition has been observed only at power-down of the AMEC
- Testing on the OV-103 launch configuration repeated the condition on the AMEC, but not significantly on the EMEC
 - The EMEC produced < 50 mV outputs
 - No switches were turned on in either the PIC rack control power assemblies (CPAs) or SRB command receiver decoders (CRDs)

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Risk Assessment:

- **Ground (post-ordnance installation)**
 - **Normal MEC power cycling after ordnance is connected is not a concern**
 - **Energy output levels are insufficient to charge PICs internal or external to the AMEC (circuit analysis)**
 - **Spurious outputs are simultaneous – PIC design requires sequenced commanding**
 - **Standard Ground Ops procedures power-down SRB and ground PIC racks prior to MEC power-down which removes power sources to PIC commands**

2. Spurious Output at Power Off	Presenter: John Hunt
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Risk Assessment (continued):

- **Pre-Launch / Pad Abort**
 - **Emergency manual MEC power-down is integral to certain pad abort scenarios**
 - **Redundant set launch sequencer (RSLs) arms the SRB IGN, Hold Down Post (HDP) and Tail Service Mast (TSM) PICs**
 - **RSLs abort processing issues MEC master reset removing ARM commands**
 - **PICs bleed off energy before a spurious output could affect the PICs (emulating a F1/F2)**
 - **RSLs master reset will always occur before MEC manual powerdown**

2. Spurious Output at Power Off	Presenter: John Hunt
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Risk Assessment (continued):

- **In-Flight**
 - MEC power-down occurs after all intended MEC functions have been executed
 - Loss of all three Orbiter main busses would be required to prematurely power-down MEC(s)
- **Catastrophic Failure**
 - The range safety system is required even in the event of a catastrophic failure of the Orbiter
 - Failure of the vehicle in such a manner as to lead to full power loss to both MECs could, theoretically, send spurious outputs to the RSS commanding their power-down
 - OV-103 AMEC/EMEC configuration would only result in the loss of redundancy, not loss of total RSS system
 - During OV-103 testing, no switches were turned on in either the PIC rack CPAs or SRB CRDs

2. Spurious Output at Power Off	Presenter: John Hunt
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Acceptance Rationale for STS-120:

- The power-down spurious outputs are insufficient in amplitude and duration to charge PICs
- Pre-flight MEC power cycling cannot adversely affect PICs due to lack of sufficient energy and incorrect sequencing
- Launch abort software safing disarms PICs such that emergency MEC power down would have no effect
- In flight, MEC power down does not occur until all intended MEC functions have been executed
 - Loss of all three Orbiter main busses would be required to prematurely power down MEC(s)

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Issue 3. Module Retention

3. Module Retention

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John Hunt

Organization/Date:

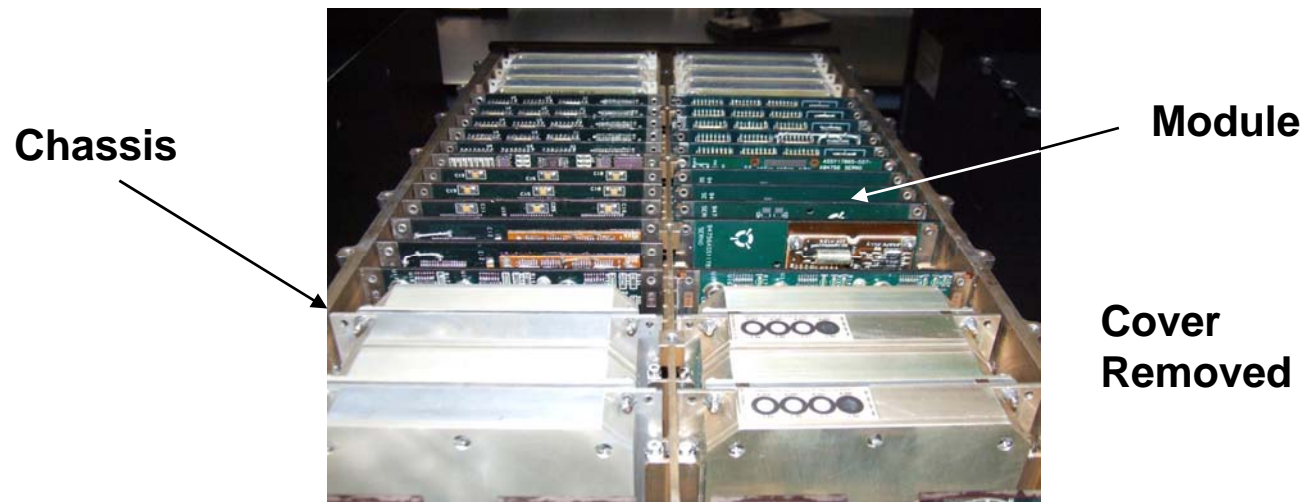
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Observation:

- EMEC s/n 0003 modules discovered raised from installed position in chassis resulting in witness marks on EMEC cover

Concern:

- Loss of function (AMEC ONLY) if module(s) were to lose continuity with backplane connector
 - EMEC cover design limits module movement - no potential for loss of continuity between card & connector



3. Module Retention

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Background:

- During repair of an EMEC s/n 0003 at the NSLD, witness marks were noted on the cover
- Modules were observed to be raised relative to the chassis
- The cards are retained by a 'wedge lock' system where the card is wedged against the chassis rails
- The system is allowing card movement in spite of proper torquing and staking of the wedge lock fasteners
- Further evaluation of the EMEC / AMEC was initiated given the observations
- It was found that a modification had previously been implemented on the AMEC cover to remove material in order to prevent interference as observed on EMEC s/n 0003
 - Mod was the result of a 1999 investigation that indicated a potential for tolerance build up between the AMEC chassis and cover that could result in interference

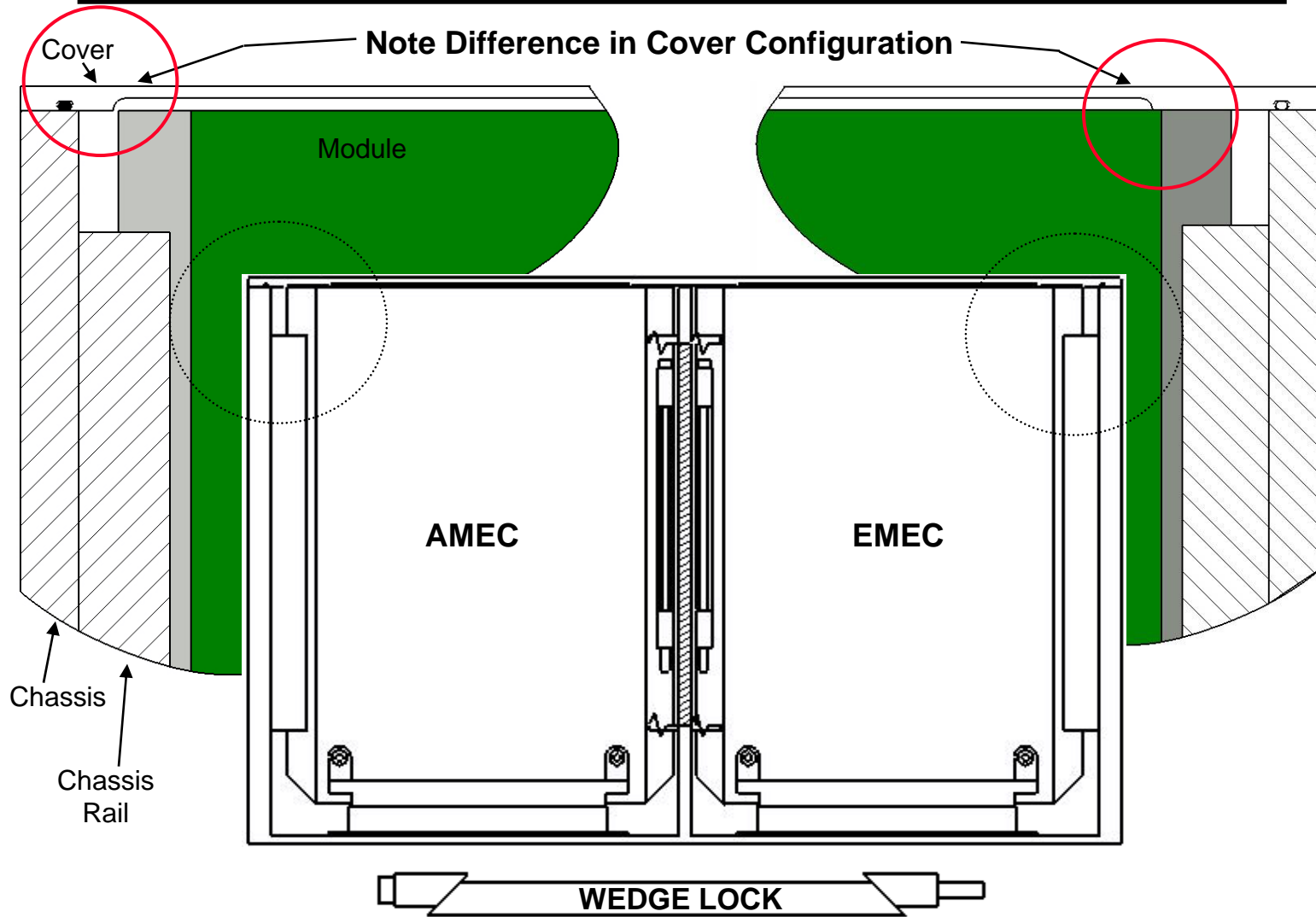
3. Module Retention

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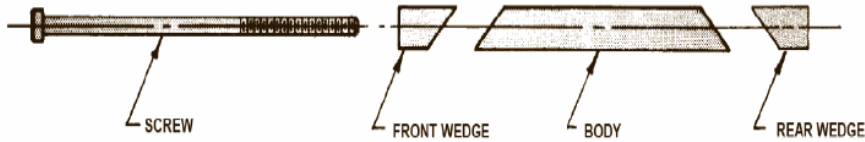
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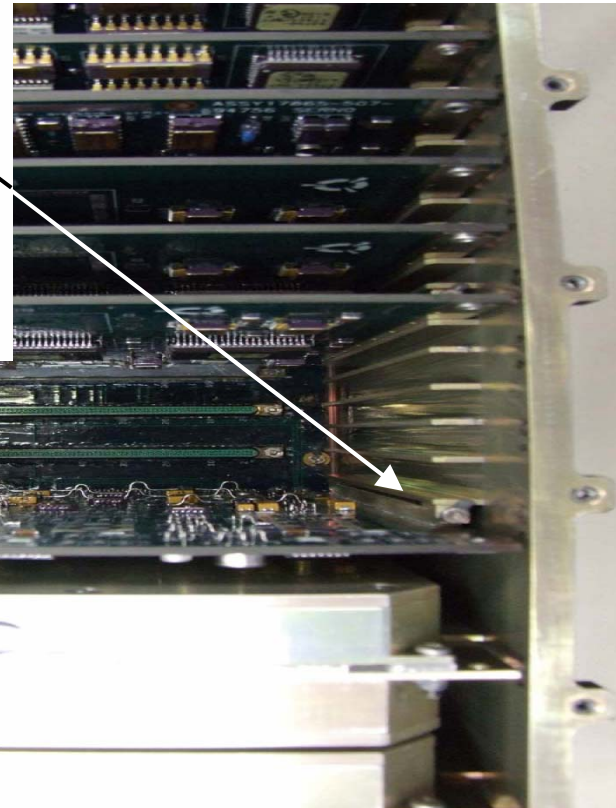
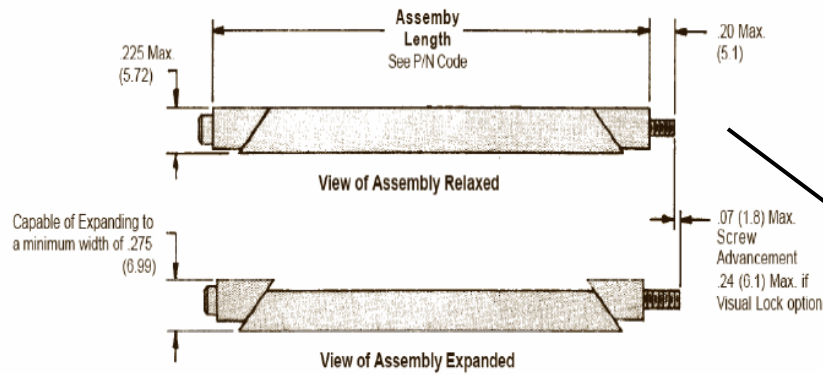
3. Module Retention

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Wedge Lock Module Retention Mechanism



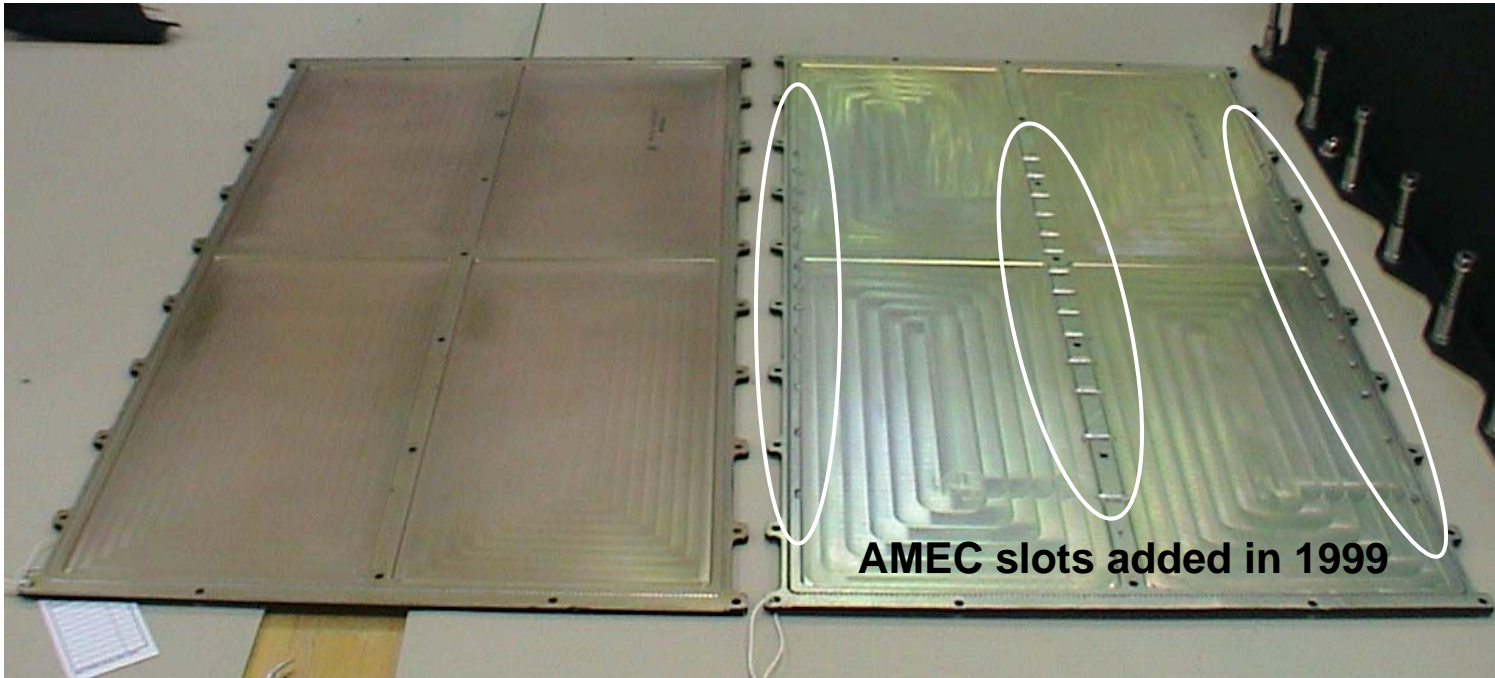
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EMEC Cover

AMEC Cover

3. Module Retention

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Actions Taken:

- Dimensional evaluation determined that, given the modification to the AMEC cover, sufficient movement could result in module connector disengagement
- To determine the precise distance required for connector demate, conductivity was measured for each module on a qual AMEC until the point of demate was reached
- This distance was then compared to the allowable gap between the module and the modified AMEC cover to determine minimum pin engagement

Measurements Based on Qual Unit				
Module	Measured Demate Distance	Nominal Cover Gap	Remaining Pin Engagement	Engagement with worst case tolerance (- 0.010")
MIA A7	0.075	0.063	0.012	0.002
MIA A25	0.071	0.063	0.008	-0.002
Driver A17	0.068	0.063	0.005	-0.005
Driver A35	0.081	0.063	0.018	0.008
PIC A21	0.077	0.063	0.014	0.004

- Worst case tolerances could allow connector disengagement

3. Module Retention

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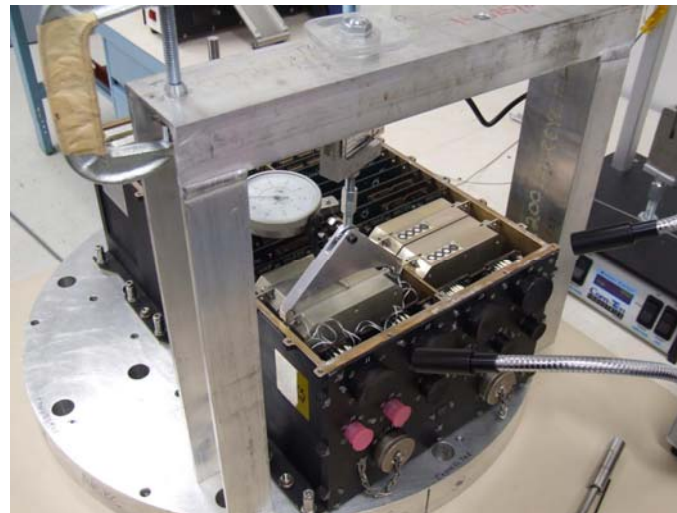
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Actions Taken (continued):

- Static pull testing shows 92-100 lbs of force required to demate a module with a properly installed wedge lock
- Static pull testing shows 30 lbs force required to demate a module without wedge locks
- At this time the root cause of the retainers allowing module movement remains unknown



3. Module Retention

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Actions Taken (continued):

- **History of EMEC s/n 0003 was evaluated**
 - The unit was repaired at the NSLD in 2004
 - All cards were established as flush during that repair
 - The EMEC flew two flights on OV-104 since 2004
 - Paper review indicates wedge locks were torqued per manufacturer's requirement and staked
- **AMEC flight history established**
 - AMECs have flown 23 missions with no failures
 - AMECs have had 32 ATP vibration tests with no failures
 - During vibe all driver outputs are monitored for proper output and redundancy
 - **AMEC 0011, installed on OV-103, has flown 5 flights**
 - AMEC 0011 circuit cards were verified flush with chassis during recent tin whisker rework
 - In 2005, AMEC 0011 passed acceptance vibration
 - AMEC 0011 has not flown since last rework

3. Module Retention

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Risk Assessment:

- Risk of losing AMEC functionality is low
 - Potential for AMEC connector demate is low with no failures in history of program
 - Witness marks have not been seen on AMEC covers
 - Static force to demate module connectors *without* wedge lock engaged is 30 lb
 - Wedge lock installed force to experience module movement is 90 lb
- AMEC s/n 0011 on OV-103 has had its modules verified flush and has not flown since
- Either core of AMEC can perform all functions
 - Loss of same function between cores is remote
- Full redundancy exists in EMEC also containing two redundant cores

3. Module Retention

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Acceptance Rationale for STS-120:

- EMEC retains dual system redundancy
 - EMEC cover design limits card movement - no potential for connector demate
 - Either core of EMEC can perform all functions
- AMEC s/n 0011 has had its modules verified flush and has not flown since
- Either core of AMEC can perform all functions
 - Loss of same function between cores is remote
- No AMEC module demate failures in history of ATP or flight