FOD Prevention at NASA-Marshall Space Flight Center

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INTRODUCTION

- NASA now requires all flight hardware projects to develop and implement a FOD Prevention Program that conforms to NAS 412 (ref. NASA-STD-6016)
- With the increasing use of composite and bonded structures, NASA now also requires an Impact Damage Protection Plan for these items (ref. MSFC-RQMT-3479)
- In 2009, Marshall Space Flight Center released an interim directive that required all Center organizations to comply with FOD protocols established by on-site Projects, to include prevention of impact damage
- The MSFC Technical Standards Control Board authorized the development of a new MSFC technical standard for FOD Prevention.
AUTHORITY

**NASA-STD-6016**
Standard Materials and Processes Requirements for Spacecraft

Requires a FOD Prevention Program for flight hardware that conforms to:

**NAS 412**
Foreign Object Damage/Foreign Object Debris (FOD) Prevention

**NASA-STD-5019**
Fracture Control Requirements for Spaceflight Hardware

**MSFC-RQMT-3479**
Fracture Control Requirements for Composite and Bonded Vehicle and Payload Structures

Susceptible structures to be protected by an:

**Impact Damage Protection Plan**

**MPD 5340.1**
Foreign Object Damage/Foreign Object Debris (FOD) Prevention Operations

**MSFC-STD-3598**
Standard for Foreign Object Damage/Foreign Object Debris (FOD) Prevention

**MSFC Project FOD Control Plans**

**MSFC Laboratory FOD Plans**
Why a MSFC FOD Directive?

- Numerous Projects, Center Organizations, and Contractors operate at MSFC and its Michoud Assembly Facility (MAF)

- An MSFC directive was needed to establish common requirements for FOD operations in MSFC facilities
  - Establishes a MSFC FOD Focal Point and MSFC FOD Database
  - Requires flight hardware Projects to assign a FOD Focal Point and establish a FOD prevention program in compliance with the directive
  - Requires that all support organizations and contractors (crane operators, facility maintenance, security, etc.) accessing FOD Sensitive Areas comply with FOD protocols and have FOD training
  - Permits Projects and Laboratories to designate high-value non-flight hardware and test facilities as FOD sensitive
Why a MSFC FOD Standard?

● To establish a common approach for FOD prevention
  – Use of common terminology and signage is necessary for communication of FOD requirements to all personnel
  – Standard FOD training is needed for support personnel accessing numerous FOD Sensitive Areas

● To tailor NAS 412 to address FOD concerns specific to MSFC hardware and facilities
  – NAS 412 was written with aircraft in mind – While establishing a sound framework for FOD prevention, it does not adequately address some FOD hazards that are of particular concern to launch vehicles and spacecraft
STATUS

● MSFC-STD-3598 Standard for Foreign Object Damage/Foreign Object Debris (FOD) Prevention was released on August 11, 2010

● MSFC Policy Directive MPD 5340.1 Foreign Object Damage/Foreign Object Debris Prevention Operations was released November 22, 2010

● A MSFC FOD training program was developed:
  ● On-line FOD Awareness Training module for facility support personnel
  ● Instructor-led training modules for FOD Sensitive Area workers, designed to be tailored for the specific Project and hardware.

● MSFC FOD Prevention Policy is now fully implemented
Now let’s talk specifics:

How does MSFC-STD-3598 tailor NAS 412?

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MSFC TECHNICAL STANDARD

STANDARD FOR FOREIGN OBJECT DAMAGE/FOREIGN OBJECT DEBRIS (FOD) PREVENTION

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CHECK THE MASTER LIST at https://repository.msfc.nasa.gov/directives.htm
VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE
The emphasis in NAS 412 is prevention of ingestion or entrapment of FOD in air-breathing aircraft
- MSFC does not manufacture or test aircraft
- MSFC does not control any aircraft runways

Launch vehicles and spacecraft, and their subcomponents, are designed, manufactured, assembled, and tested at MSFC facilities
FOD Sensitive MSFC Products

- Large scale propulsion systems, especially Liquid Oxygen/Liquid Hydrogen systems
- Large scale composite and bonded structures
- Pressure Vessels – Composite Overwrap, Titanium
- Large space telescope optic components
- Environmental Control Life Support Systems
- Test facilities – Propulsion Test, Thermal Vacuum Chambers
FOD Hazards for MSFC Products

- **Entrapment of small items:**
  - Plug or restrict fluid supply lines and vent lines
  - Cause an ignition within liquid propellant systems
  - Interfere with mechanical actuators, pumps, switches, or valves
  - Cause impact damage when the FOD is shaken loose during transportation, handling, dynamic tests, or launch
  - Cause open or short circuits in electrical connectors
  - Become liberated on orbit, potentially endangering crew
Impact Damage

- Spacecraft are designed to be as lightweight as possible; leading to hardware that is vulnerable to impact damage during ground processing.
- The sheer size of launch vehicles makes hardware handling particularly challenging.
- Composite and bonded structures are increasingly being used in launch vehicles and spacecraft; these may be vulnerable to impact damage that is not visually apparent on the hardware surface.
Leaks, Drips, and Spills

- Serious and very costly damage has occurred, or nearly occurred, over the years from facility failures in the aerospace industry. Examples:
  
  - A facility water valve failed, flooding a room overnight where flight hardware was ready to ship but was uncovered.
  - A fire-suppression sprinkler head failed, dowsing highly sensitive hardware.
  - A water-soaked ceiling tile fell, very close to flight hardware.
  - Crane drips, roof leaks, and plumbing failures are a constant concern in aging facilities.
Addressing MSFC FOD Hazards

- The FOD Prevention Program structure in NAS 412, which focuses primarily on entrapment, readily lends itself to control of impact sources and leak hazards with only minor modifications:
  - Added emphasis on facilities as a major source of FOD
    - Require a facility FOD risk review prior to activation of any new FOD Sensitive Area
  - Restriction and control of overhead operations in all FOD sensitive areas regardless of level of control
  - FOD Control Plans are required to identify Impact Damage Susceptible (IDS) items as well as items susceptible to entrapment.
  - FOD Training to address entrapment, impact, and leaks
  - Workers are instructed to also LOOK UP during FOD walkdowns
MSFC FOD Program Features

- MID 5340.1 and MSFC-STD-3598 adopt common terms and strategies from both NAS 412 and heritage FOD prevention programs used for Space Shuttle operations
  - United Space Alliance FOD Program at Kennedy Space Center
  - Lockheed Martin FOD Program at MSFC-Michoud Assembly Facility
  - Also benchmarked other aerospace industry FOD programs

- Key is the adoption of three levels of FOD Sensitive Area, with corresponding levels of access restriction and operational control:
  - FOD Awareness Area
  - FOD Control Area
  - FOD Critical Zone

- Both entrapment-sensitive and IDS hardware are designated as FOD-sensitive
Required Elements of FOD Control

- **Design Consideration for FOD Prevention:**
  - Damage Tolerance (impact, corrosion, contamination)
  - Screens, caps, and covers

- **Control of Manufacturing and Test Operations**
  - Identify and control FOD Sensitive Areas
  - Tool controls for hand tools, fasteners, shop consumables, etc.
  - Housekeeping and Clean-As-You-Go methods
  - Precautions for lifting, handling, and moving FOD sensitive items

- **Facility risk assessment and cleaning prior to FOD area activation**
  - Remove loose debris, make repairs/mitigations

- **FOD Prevention Training**
  - Train all personnel with access to FOD Sensitive Areas
  - Access controls and escort for non-trained personnel

- **Measurement, Trending, and Feedback**
  - Incident/Mishap reporting system, trend tracking
  - Routine area inspections and reporting
  - Near-Miss reporting and corrective action
MSFC-STD-3598 requires the use of common signage to assure easy recognition of the presence of FOD sensitive hardware.

- FOD Awareness Area
- FOD Control Area
- FOD Critical Zone

The NO FOD logo is encouraged for use on ALL FOD signage and awareness media.
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¹. Required for FOD Monitors and FOD Site Managers only.
². All loose items shall be tethered, secured, or removed when over IDS hardware.

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**Work rules are tailored, within specified limits, by the Project FOD Focal Point and each FOD Site Manager**
# FOD Area Agreement

## FOD CONTROL AREA

**FOD Sensitive Area Requirements**

<table>
<thead>
<tr>
<th>Process:</th>
<th>State Operation Here</th>
<th>Location:</th>
<th>Enter Building and Room or Zone here</th>
<th>Start Date:</th>
<th>Click here to enter a date.</th>
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<tr>
<td>FOD Focal Point</td>
<td>Project FOD Focal Point</td>
<td>Phone</td>
<td>Phone number</td>
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**FOD Risk:** Specify Impact Damage Susceptible Hardware, FOD entrapment concerns, other risks

## FOD Work Rules for this Area

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<tr>
<th>PEOPLE</th>
<th>TOOLS</th>
<th>OPERATIONS</th>
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</thead>
<tbody>
<tr>
<td>List work rules for operations</td>
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</tr>
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*Work Rules that everyone must follow in this area*

## Site Manager Contact info--

- **Site Manager:**
  - Click here to enter text.
  - **Phone:**
    - Click here to enter text.

## After hours emergency contact--

- **After Hours Emergency Contact:**
  - Click here to enter text.
  - **Phone:**
    - Click here to enter text.
• FOD Sensitive Areas will be clearly marked with:

Access control: door locks, ropes, etc
A FOD sign with logo showing the LEVEL of FOD control
A FOD Area Agreement that shows:
  – The FOD sensitive hardware being processed
  – Work Rules for PEOPLE, TOOLS, and OPERATIONS
  – Contact information
Summary

- MSFC Policy Directive MPD 5340.1 requires FOD prevention for all flight hardware projects, and requires all support organizations to comply.
- MSFC-STD-3598 implements a standard approach for FOD prevention, tailored from NAS 412.
- Three levels of FOD Sensitive Area are identified, adopting existing practices at other NASA facilities.
- Additional emphasis is given to prevention of impact damage and mitigation of facility FOD sources, especially leaks and spills.
- Impact Damage Susceptible (IDS) items are identified as FOD-sensitive as well as hardware vulnerable to entrapment of small items.
Questions?