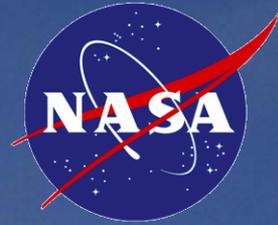


National Aeronautics and  
Space Administration



# FOD Prevention at NASA-Marshall Space Flight Center



*Nikki M. Lowrey  
Sr. Contamination Control Engineer  
Jacobs ESTS Group  
32<sup>nd</sup> NAFPI Conference, Dallas, TX  
August 16-18, 2011*

**JACOBS**

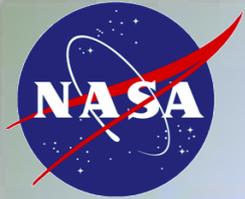


# INTRODUCTION

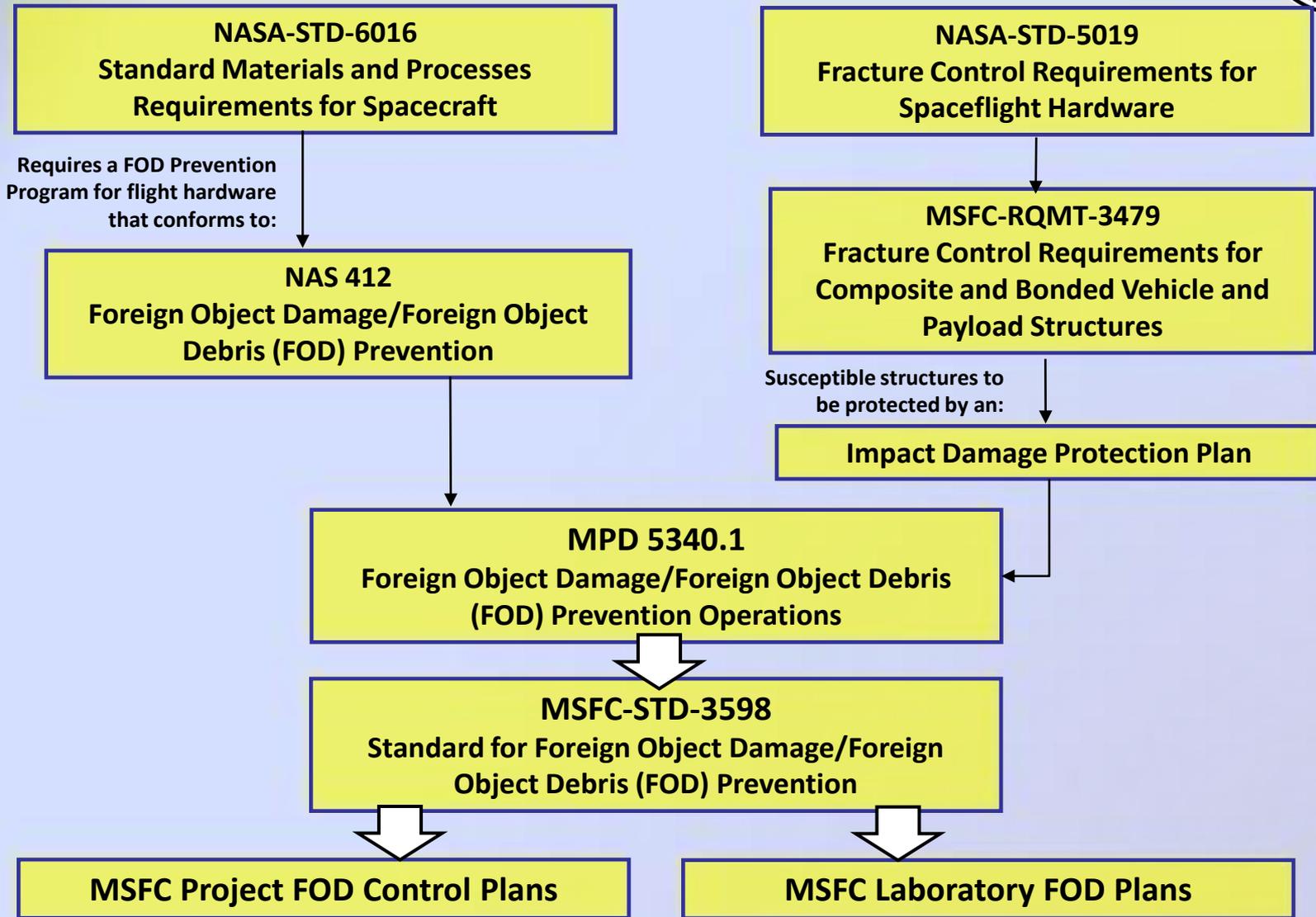
---

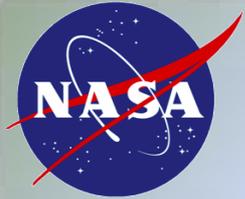


- **NASA now requires all flight hardware projects to develop and implement a FOD Prevention Program that conforms to NAS 412 (ref. NASA-STD-6016)**
- **With the increasing use of composite and bonded structures, NASA now also requires an Impact Damage Protection Plan for these items (ref. MSFC-RQMT-3479)**
- **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



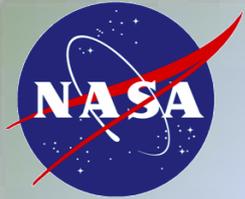


# Why a MSFC FOD Directive?

---



- **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

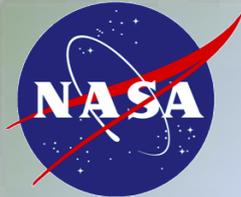


# STATUS

---



- **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?

**Aerospace Industries Association**  
Flight Test Operations Group

**NATIONAL AEROSPACE STANDARD**  
© COPYRIGHT 1997 AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC. ALL RIGHTS RESERVED

PARAGRAPH	CONTENTS	SHEET
1.0	Purpose	2
2.0	Introduction	3
3.0	FOD Advisory Board	3
4.0	General	4
4.1	Scope	4
4.2	Definitions	4
4.3	References	5
5.0	Implementation Control Methods	6
5.1	Measuring Performance	7
5.2	Training	7
5.3	Material Handling and Parts Protection	8
5.4	Housekeeping	9
5.5	Tool Accountability	9
5.6	Hardware Accountability	10
5.7	Lost Items	10
5.8	Hazardous Material	10
5.9	Physical Entry into FOD Critical Areas	10
5.10	Focal Point	11
6.0	Design Considerations	12
7.0	Assembly Operations	13
8.0	Test Cell Environment	14
9.0	Field Operations	15
10.0	Reporting/Investigation	16
11.0	National Aerospace FOD Prevention, Inc.	18

**TITLE**  
FOREIGN OBJECT DAMAGE/  
FOREIGN OBJECT DEBRIS (FOD) PREVENTION

**NAS 412**  
Sheet 1 of 18

APPROVAL DATE: 06/11/97

USE OF OR RELIANCE UPON THIS DOCUMENT OR ANY NATIONAL AEROSPACE STANDARD IS ENTIRELY VOLUNTARY. AIA DOES NOT QUALIFY SUPPLIERS OR CERTIFY CONFORMANCE OF ITEMS FURNISHED UNDER NATIONAL AEROSPACE STANDARDS. AIA MAKES NO REPRESENTATION OR CLAIM RESPECTING (1) THE SUITABILITY OF ITEMS FOR ANY PARTICULAR APPLICATION OR (2) THE ABSENCE OF OR APPLICABILITY THEREOF TO PATENT OR TRADEMARK RIGHTS.

STD-AIA/NAS NAS 412-ENGL 1,997 ■ 0318743 0505351 T60 ■

Copyright Aerospace Industries Association of America, Inc.  
Printed on 8 1/2 x 11 in. paper with 25/100 dots  
No reproduction or retransmission without express written permission

Copyright © 1997 Aerospace Industries Association of America, Inc.  
Printed on 8 1/2 x 11 in. paper with 25/100 dots  
No reproduction or retransmission without express written permission



**NASA**

National Aeronautics and  
Space Administration

George C. Marshall Space Flight Center  
Marshall Space Flight Center, Alabama 35812

MEASUREMENT  
SYSTEM  
NOT APPLICABLE

MSFC-STD-3598  
BASELINE  
EFFECTIVE DATE: August 11, 2010

EM50

MSFC TECHNICAL STANDARD

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

Approved for Public Release; Distribution is Unlimited

CHECK THE MASTER LIST at <https://repository.msfc.nasa.gov/directives.htm>.  
VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE





# MSFC Products versus NAS 412



- 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



**JACOBS**



# 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





# FOD Hazards for MSFC Products



- **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.



An Ares I Upper Stage Common Bulkhead Dome



**JACOBS**



# FOD hazards for MSFC Products



- **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



# Common Signage



- 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**



# Standard FOD Work Rules



**FOD Control Area Work Rules - Quick Reference Guide**

	FOD Awareness Area	FOD Control Area	FOD Critical Zone
Sign			
Training Requirements	FOD Awareness	FOD Prevention FOD Monitor <sup>1</sup>	FOD Prevention FOD Monitor <sup>1</sup> FOD Critical Zone
Visitors	Permitted with approval of the Site Manager	Permitted with trained escort	Not Allowed
Area Agreement Posted	Optional	Required	Required
FOD Awareness Banners	Recommended	Recommended	Not permitted
Food and Drinks	Not Allowed (except in closed containers)	Not Allowed	Not Allowed
Personal Items	Not restricted <sup>2</sup>	No loose items above the waist <sup>2</sup>	No loose items permitted
Jewelry	Not restricted <sup>2</sup>	Removed or secured	Removed or secured
Eyeglasses	Not restricted <sup>2</sup>	Tethered	Tethered
Tool Controls	Not required <sup>2</sup>	Controlled, tethered over IDS hardware	Tethered, logged, and tracked
Small Parts control	Not required <sup>2</sup>	Controlled	Kitted and counted
Lost Tools/Items	Report	Report Immediately	Report Immediately
Dropped Tools/Items	Report IDS hardware contact immediately	Report Immediately if IDS hardware is present	Report Immediately if IDS hardware is present
Scheduled FOD Walk Downs	Optional	Daily, beginning of shift	Visual inspection on entry and exit of Zone
1. Required for FOD Monitors and FOD Site Managers only. 2. All loose items shall be tethered, secured, or removed when over IDS hardware.			

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





# FOD Area Agreement

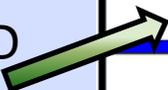


		<b>Enter Project Name Here</b> Foreign Object Debris (FOD) Prevention Program			
<b>FOD CONTROL AREA</b>					
<b>FOD Sensitive Area Requirements</b>					
Process: State Operation Here		Location: Enter Building and Room or Zone here		Start Date: <a href="#">Click here to enter a date.</a>	
				FOD Focal Point Project FOD Focal Point	Phone Phone number
FOD Risk: Specify Impact Damage Susceptible Hardware, FOD entrapment concerns, other risks					
<b>FOD Work Rules for this Area</b>					
<b>PEOPLE</b>		<b>TOOLS</b>		<b>OPERATIONS</b>	
<ul style="list-style-type: none"> <li>List work rules for operations</li> <li></li> </ul>		<ul style="list-style-type: none"> <li>List work rules for operations</li> <li></li> </ul>		<ul style="list-style-type: none"> <li>List work rules for operations</li> <li></li> </ul>	
<i>Work Rules that <u>everyone</u> must follow in this area</i>					
<b>APPROVALS</b>					
Site Manager: <a href="#">Click here to enter text.</a>		Facility Operations POC: <a href="#">Click here to enter text.</a>		After Hours Emergency Contact <a href="#">Click here to enter text.</a>	
Phone <a href="#">Click here to enter text.</a>		Phone <a href="#">Click here to enter text.</a>		Phone <a href="#">Click here to enter text.</a>	

Level of FOD control



The FOD Risk



Site Manager Contact info



After hours emergency contact--





# Marking of FOD Sensitive Areas



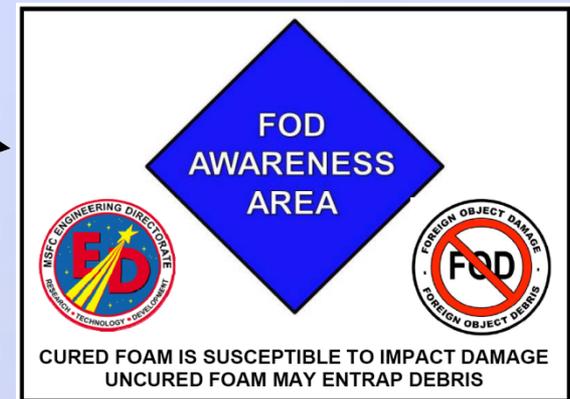
- FOD Sensitive Areas will be clearly marked with:

**Access control:** door locks, ropes, etc

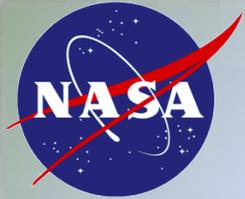
**A FOD sign** with logo showing the LEVEL of FOD control

**A FOD Area Agreement** that shows:

- The FOD sensitive hardware being processed
- Work Rules for PEOPLE, TOOLS, and OPERATIONS
- Contact information



Enter Project Name Here Foreign Object Debris (FOD) Prevention Program <b>FOD CONTROL AREA</b> FOD Sensitive Area Requirements			
Process: State Operation Here	Location: Enter Building and Room or Zone here	Start Date: Click here to enter a date. FOD Fiscal Point Project FOD Fiscal Point	Phone Phone number
FOD Risk: Specify Impact Damage Susceptible Hardware, FOD entrapment concerns, other risks			
<b>FOD Work Rules for this Area</b>			
<b>PEOPLE</b> • List work rules for operations	<b>TOOLS</b> • List work rules for operations	<b>OPERATIONS</b> • List work rules for operations	
<b>APPROVALS</b>			
Site Manager: Click here to enter text.	Facility Operations POC: Click here to enter text.	After Hours Emergency Contact: Click here to enter text.	
Phone: Click here to enter text.	Phone: Click here to enter text.	Phone: Click here to enter text.	



# Summary

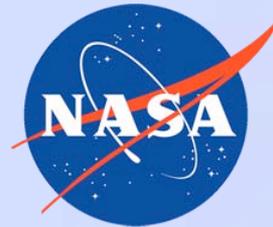
---



- **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?*



[www.nasa.gov](http://www.nasa.gov)

**JACOBS**