

The Impact of Triboelectrification

On the

Ares I-X Launch

And

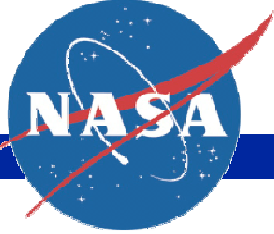
Considerations for Other Launch Vehicles

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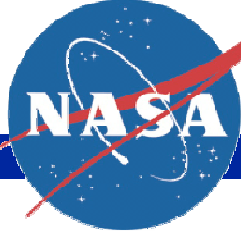
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Overview

- **Lightning Launch Commit Criteria**
- **Triboelectrification Description**
- **Ares I-X Case**
 - **Timeline**
 - **Scrub**
- **Contributing Factors**
- **Recommendations**

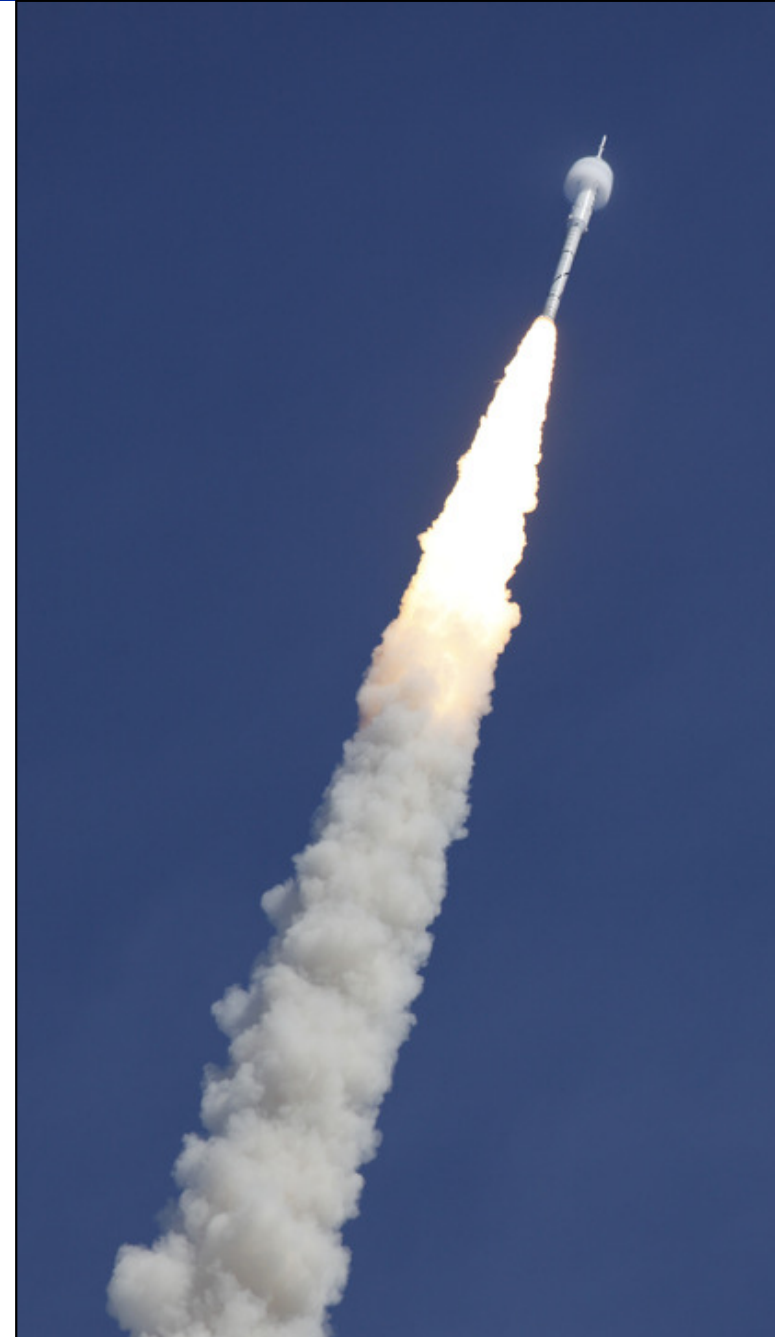


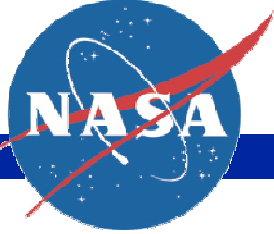


Lightning Launch Commit Criteria

- Apply to all launch vehicles
- Generally protect the vehicle from natural or triggered lightning
- Triboelectrification – customers not as familiar with this rule because all vehicles on the Eastern Range cleared for over a decade
- Ares I-X
 - New vehicle
 - Not cleared
 - “Tribo” rule included in the Range

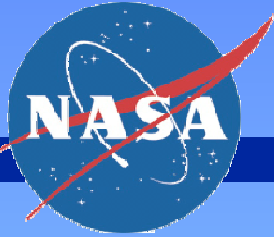
Lightning Launch Commit Criteria
(LLCC)





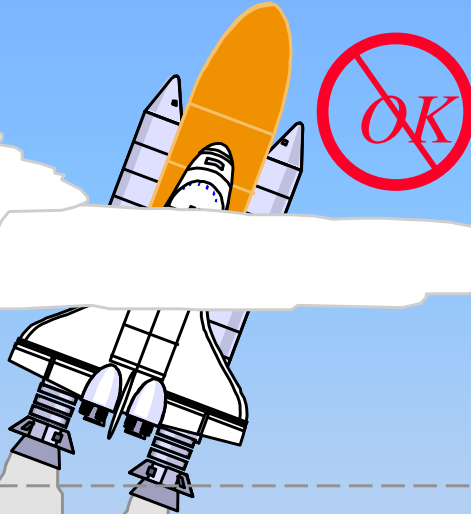
What is Triboelectrification?

- **Triboelectrification:** The transfer of electrical charge between ice particles and the launch vehicle when the ice particles collide with the vehicle during flight
- **Triboelectrification Lightning Launch Commit Criteria** restricts flight through clouds at -10°C or colder if the launch vehicle is not properly bonded or treated when velocity is less than 3,000 ft/sec
- **When Ares I-X Launch Commit Criteria** were identified, all Eastern Range vehicles were cleared from the triboelectrification rule for over a decade



Triboelectrification

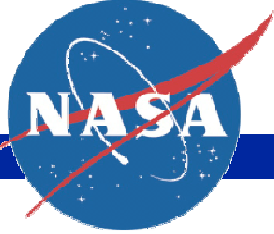
Velocity < 3000 ft/sec



-10 °C

DON'T launch if a vehicle has not been treated or tested for surface electrification and the flight path will go through any clouds -10 °C or colder and the vehicle's velocity is

less than 3000 ft/sec



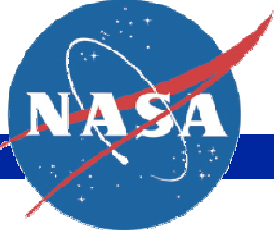
Triboelectrification

UNLESS

- The launch vehicle is treated for surface electrification;

OR

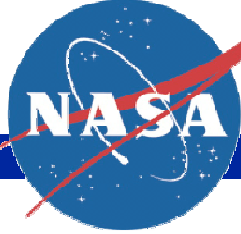
- A launch operator has previously demonstrated by test or analysis that electrostatic discharges on the surface of the launch vehicle caused by “triboelectrification” will not be hazardous to the launch vehicle or the spacecraft



Triboelectrification: “Treated”

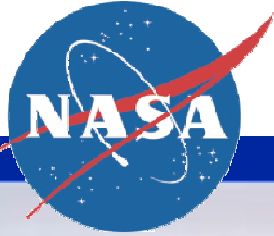
A launch vehicle is treated for surface electrification if . . .

- (1) All surfaces of the launch vehicle susceptible to ice particle impact are such that the surface resistivity is less than 10^9 ohms/square; and
 - *Yes, ohms/square!*
- (2) All conductors on surfaces (including dielectric surfaces that have been treated with conductive coatings) are bonded to the launch vehicle by a resistance that is less than 10^5 ohms



Electrostatic Hazards & Launches

- **Electrostatic Effects**
 - **Triboelectric charging**
 - **Induction charging**
 - **Engine-exhaust charging**
- **Electrostatic Effects suspected in failures of several launches**
 - **Europa II Failure**
 - **Two Minuteman Failures**
 - **Two Titan III Guidance Anomalies**
 - **Two Scout Failures**



Ares I-X

- First new vehicle from LC39 at Kennedy Space Center since the first Space Shuttle in 1981
- Flight demonstration model for the Ares I vehicle being developed by NASA under the Constellation program
- Was not treated or tested for triboelectrification

Not Cleared



Ares I-X

Cleared



Space Shuttle

Cleared

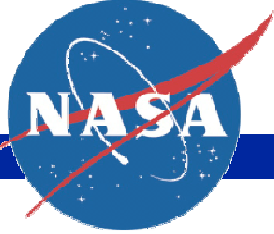


Delta

Cleared



Atlas

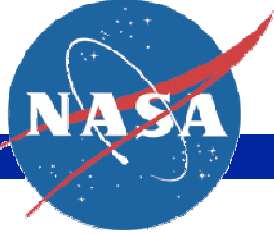


Ares I-X Case

- **July 2008**
 - **Triboelectrification briefed at Ares I-X Lightning Technical Interchange Meeting**
- **January 2009**
 - **During development of Ares I-X LLCC, Eastern Range informed the NASA LLCC team if vehicle is not treated or tested, triboelectrification LLCC must be included**



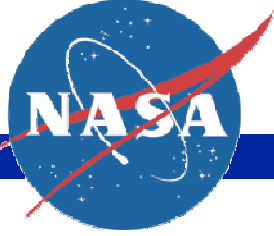
LLCC = Lightning Launch Commit Criteria



Ares I-X Case

- **March 2009:**
 - **MSFC Natural Environments confirmed there was no design requirement for preventing triboelectrification**
 - **MSFC Natural Environments analyzed climatology of high clouds and determined low impact for Apr-Jun**
 - **Triboelectrification included in the launch rules**
 - **Launch delayed until Oct 09 – more risk of high clouds**
- **October 2009:**
 - **Launch Scrub due to triboelectrification**

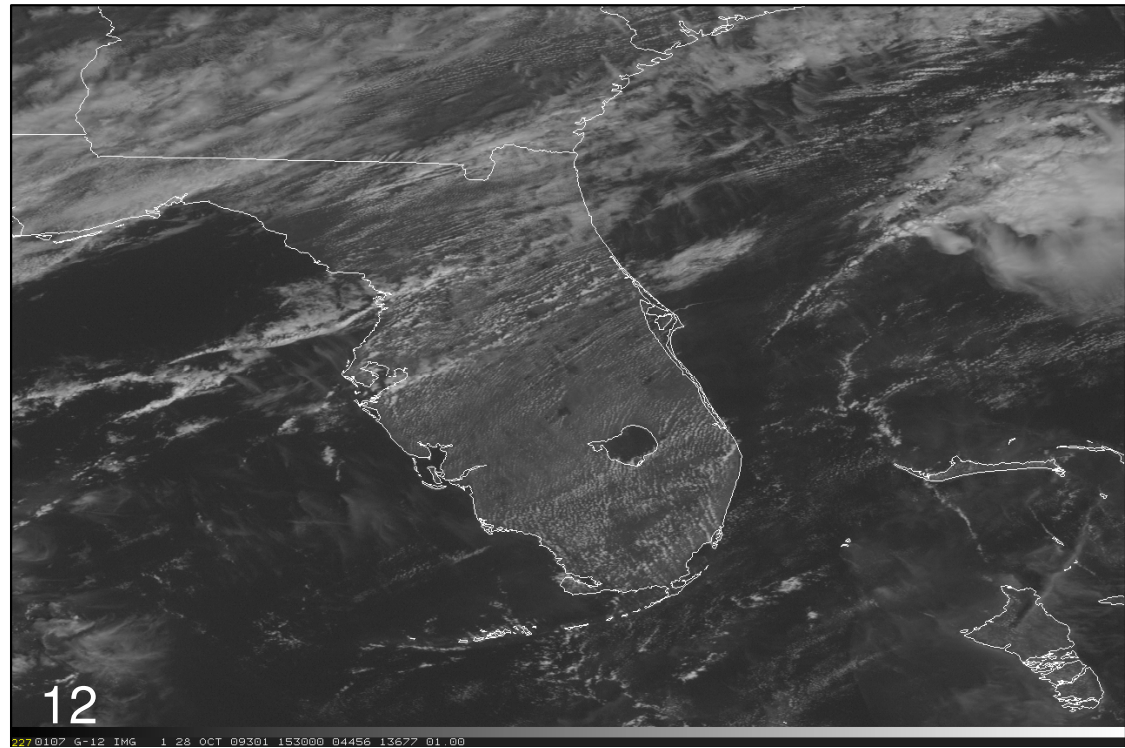


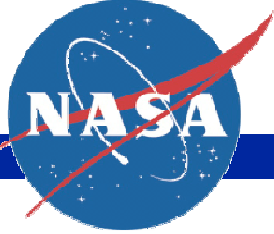


Ares I-X, 27 – 28 October 2009

- High, thin clouds prevalent on launch attempt days
 - 27 October attempt *scrubbed* – triboelectrification LLCC violated through launch window
 - 28 October attempt *delayed* -- aircraft helped us find a hole in the clouds and we finally *launched!*

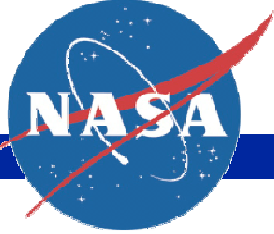
*“We were battling
... high thin
cirrus....”*





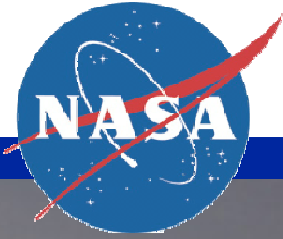
Contributing Factors

- **Decision makers did not fully understand the impact of the triboelectrification rule**
- **Climatology for original launch date showed low-impact, but launch date slipped**
- **Ares I-X decision makers did not have experience with Triboelectrification rule – was not in the Shuttle Launch Commit Criteria**



Recommendations

- **Launch Ranges: Always include triboelectrification rule in the Launch Commit Criteria**
 - If the caveats are met, evaluate the rule as **“GREEN”**
- **All vehicle programs should evaluate electrostatic hazards, including triboelectrification, during design phase**
- **When triboelectrification applies as a lightning launch commit criteria, strongly consider the use of a weather reconnaissance aircraft to observe cloud, especially if a climatological analysis indicates a risk for clouds**
 - **Ares I-X prime example**



Questions?

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