

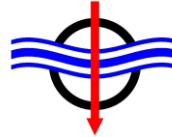


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# SpaceCraft Object Risk Evaluation Database (SCORED)

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PR00089/D88

# Objectives

- Improvement of Space Debris Risk Methodologies
  - Database of recommended models
    - Material level, component level, uncertainties
    - High current dependence on modeller
- Destructive Re-entry Analyses
  - How to model components for ground casualty risk assessment?
  - Database contains recommended material models
  - Database now contains standard models for specific components
    - Reaction wheel model has been derived for DRAMA / SAMj
    - 1N Thruster & fill / drain valve models developed in this work
- Hypervelocity Impact Analyses
  - How to model the stack?
  - Database will contain standard models for specific components
    - Electronics box penetration
    - Harness (at a distance from panel)

# Three Tracks

Software

Flexible Database Model

Export Functionality

Destructive Re-entry

Materials Database

Components Database

Hypervelocity Impact

Materials Database

Components Database

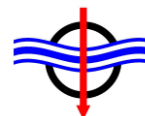


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# Software

- Single instance hosted by ESA
  - Models stored in Postgres database
  - Data maintenance performed using Django / Python web application

SCORED Administration WELCOME, JOHN. [VIEW SITE](#) / [CHANGE PASSWORD](#) / [LOG OUT](#)

Home > Scored > Materials - Simple DRE

Start typing to filter...

**SCORED**

- Components + Add
- DRE - Components + Add
- DRE - Tags + Add
- HVI - BLE Template Coefficients + Add
- HVI - BLE Templates + Add
- HVI - BLEs + Add
- HVI - Components + Add
- HVI - Inner Bumpers + Add
- HVI - Outer Bumpers + Add
- HVI - Tags + Add
- HVI - Targets + Add
- Materials + Add

Select Simple DRE Material Model to change RECOVER DELETED MATERIALS - SIMPLE DRE ADD SIMPLE DRE MATERIAL MODEL +

Search:  Search

Action:  Go 0 of 22 selected

<input type="checkbox"/>	NAME	MATERIAL	Material tags	Last Modified
<input type="checkbox"/>	A316	A316	Drama 3.0.4, Drama 3.1.0	None, Jan. 1, 1970, midnight
<input type="checkbox"/>	AA2195 (Al-Li)	AA2195 (Al-Li)	Drama 3.0.4, Drama 3.1.0	None, Jan. 1, 1970, midnight
<input type="checkbox"/>	AA7075	AA7075	Drama 3.0.4, Drama 3.1.0	None, Jan. 1, 1970, midnight
<input type="checkbox"/>	Bat-Li	Bat-Li	Drama 3.0.4, Drama 3.1.0	None, Jan. 1, 1970, midnight
<input type="checkbox"/>	Bat-NiCd	Bat-NiCd	Drama 3.0.4, Drama 3.1.0	None, Jan. 1, 1970, midnight
<input type="checkbox"/>	Beryllium	Beryllium	Drama 3.1.0	None, Jan. 1, 1970, midnight
<input type="checkbox"/>	Brass	Brass	Drama 3.0.4, Drama 3.1.0	None, Jan. 1, 1970, midnight
<input type="checkbox"/>	Carbon-Carbon	Carbon-Carbon	Drama 3.0.4, Drama 3.1.0	None, Jan. 1, 1970, midnight

**FILTER**

- ↓ By name
  - All
  - Drama 3.0.4
  - Drama 3.1.0
  - Sesam
- ↓ By modified at
  - Any date
  - Today
  - Past 7 days
  - This month
  - This year

# Software

- Data exports for current clients
  - DRAMA/SESAM material and component databases
  - DRAMA/MIDAS BLE and component definitions
- Potential future 3<sup>rd</sup> party application connectivity using RESTful API

The screenshot displays the SCORED Administration web interface. The header includes the title "SCORED Administration" and user information "WELCOME, JOHN. VIEW SITE / CHANGE PASSWORD / LOG OUT". The breadcrumb trail is "Home > Scored > Materials - Simple DRE".

On the left, there is a sidebar menu with the following items, each with a "+ Add" button:

- SCORED
- Components
- DRE - Components
- DRE - Tags
- HVI - BLE Template Coefficients
- HVI - BLE Templates
- HVI - BLEs
- HVI - Components
- HVI - Inner Bumpers
- HVI - Outer Bumpers
- HVI - Tags
- HVI - Targets
- Materials

The main content area is titled "Select Simple DRE Material Model to change". It features a search bar, a "RECOVER DELETED MATERIALS - SIMPLE DRE" button, and an "ADD SIMPLE DRE MATERIAL MODEL +" button. Below the search bar, there is an "Action:" dropdown menu and a "Go" button, with the text "0 of 22 selected".

The main table lists the material models with the following columns: NAME, MATERIAL, Material tags, and Last Modified. The table contains 12 rows of data:

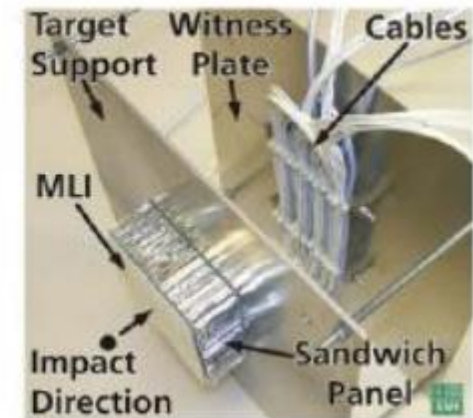
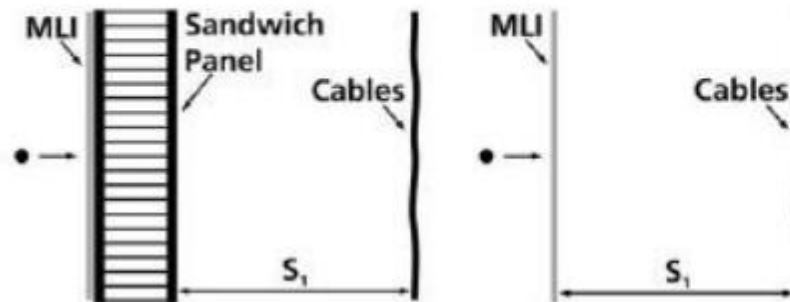
<input type="checkbox"/>	NAME	MATERIAL	Material tags	Last Modified
<input type="checkbox"/>	A316	A316	Drama 3.0.4, Drama 3.1.0	None, Jan. 1, 1970, midnight
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<input type="checkbox"/>	Brass	Brass	Drama 3.0.4, Drama 3.1.0	None, Jan. 1, 1970, midnight
<input type="checkbox"/>	Carbon-Carbon	Carbon-Carbon	Drama 3.0.4, Drama 3.1.0	None, Jan. 1, 1970, midnight

On the right side, there is a "FILTER" panel with two sections:

- By name:** All, Drama 3.0.4, Drama 3.1.0, Sesam
- By modified at:** Any date, Today, Past 7 days, This month, This year

# Hypervelocity Impact

- HVI effect is based on Ballistic Limit Equations (BLEs)
  - Range of existing BLEs
  - Selection is important
  - Database output will guide the user on which BLE
    - Component and shield parameter ranges (e.g. density, thickness, spacing) identify applicable geometry
    - Failure criterion (e.g. spallation, penetration) define BLE
- Model for electrical harness
  - Data exists on harness impact at a distance from a wall
  - BLEs re-derived for use in database



# Hypervelocity Impact – initial data set

- 22 material models including
  - Aluminium, aluminium alloy, steel, CFRP, titanium
- Component models
  - Electrical harness protected by aluminium or CFRP sandwich panel
  - Unprotected electronics box
  - Electronics box protected by aluminium plate
  - Electronics box aluminium or CFRP sandwich panel
  - Unprotected fused silica glass (optical instrument)
  - Unprotected titanium tank
- BLEs
  - All existing MIDAS BLE definitions
  - Specific BLE definitions for each component / protection / failure criterion combination

# Destructive Re-entry

- Development of Thruster Model
  - Scrap 1N thrusters obtained from ArianeGroup
  - Plasma wind tunnel test campaign
    - Material testing (Haynes 25, Inconel 718)
    - Parts testing
    - Mock-up nozzle testing to understand scaling
    - Complete thruster testing
- Two test campaigns
  - Parts tested in L2K, complete thrusters in L3K

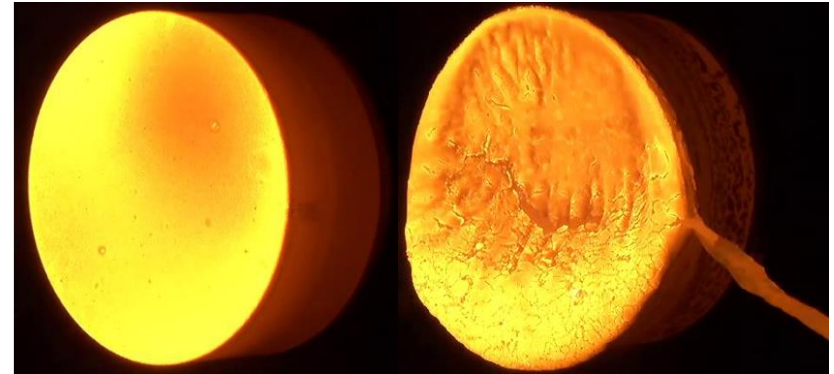




# Destructive Re-entry

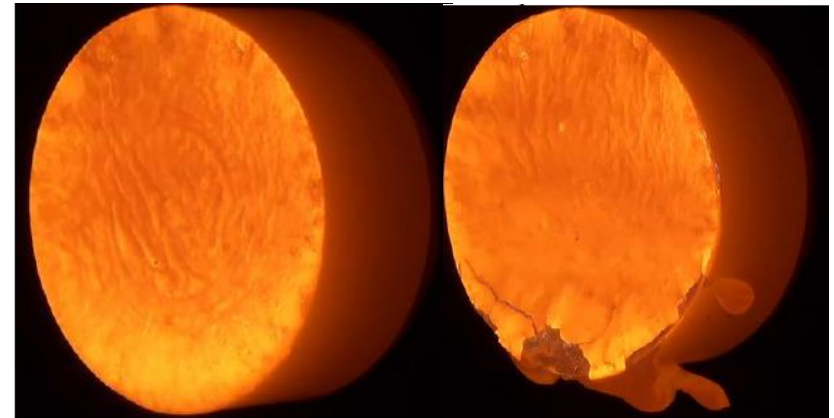
- Haynes 25

- Does not melt at melt temperature
  - Surface  $>200^{\circ}\text{C}$  above
- Very strong oxide layer
  - Insulates material, holds liquid inside
  - Had to go to maximum power in L2K to release melt
    - Much higher than expected
  - Melt model is not appropriate – proxy model required
  - Reasonably low catalycity material; very high emissivity (0.95)



- Inconel 718

- Has strong oxide layer
- Does melt when it is supposed to
  - Still high temperature
- Existing models are reasonable
- Emissivity is high (0.9)



# Destructive Re-entry – Thruster Parts

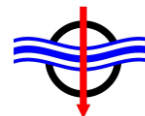
- Titanium tubing
  - Small radius – fast melt
  - Not major risk
- Haynes 25 parts
  - Different behaviour for thin and thick material
  - Thin material tears at melt temperature
  - Thick material has thick protective oxide
  - Different models required
- Very low demisability



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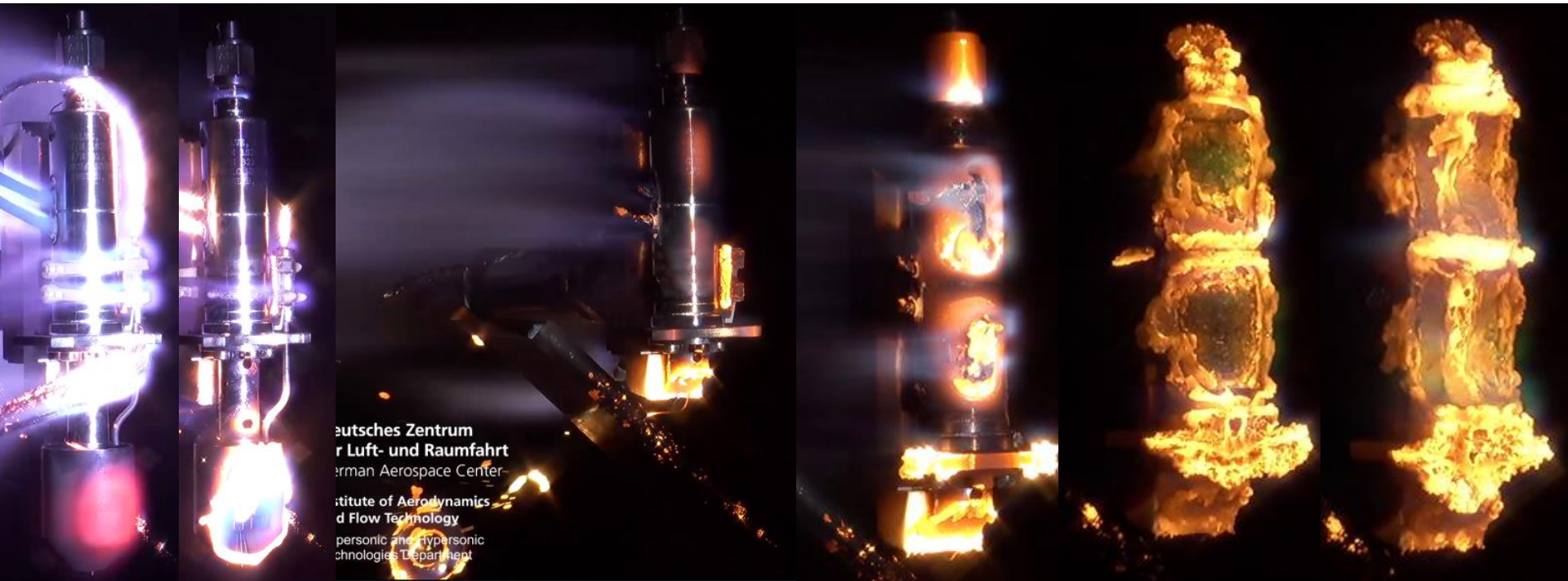


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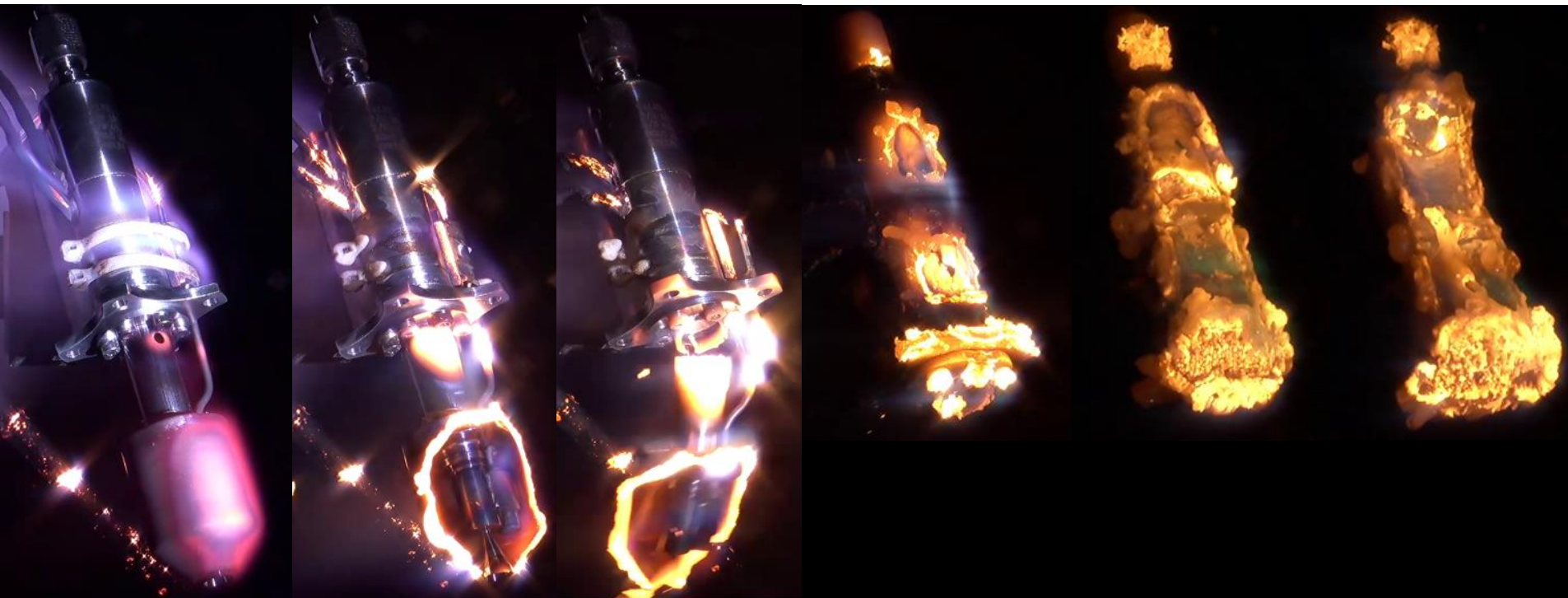
# Complete Thruster Tests

- Full Thruster (90°)
  - Cabling shears / fast melt of heatshield
  - Fragmentation of lower nozzle
  - Significant delay in melting of large inlet part due to outgassing
  - Melt starts up again once outgassing stops
- Demise slower than part tests
  - Slower than stepped approach – driven by outgassing



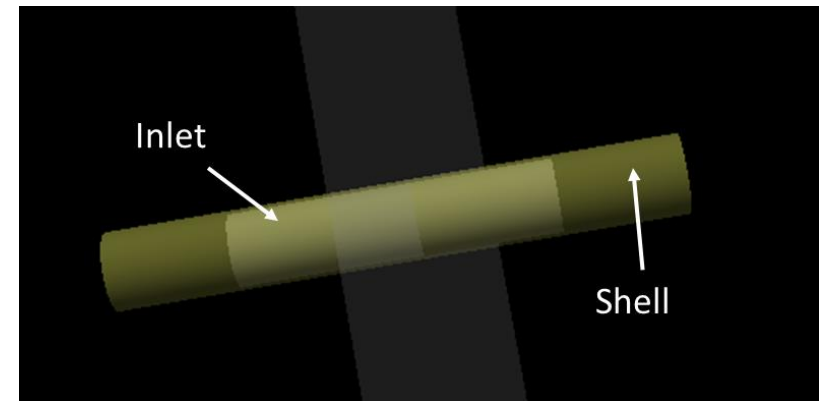
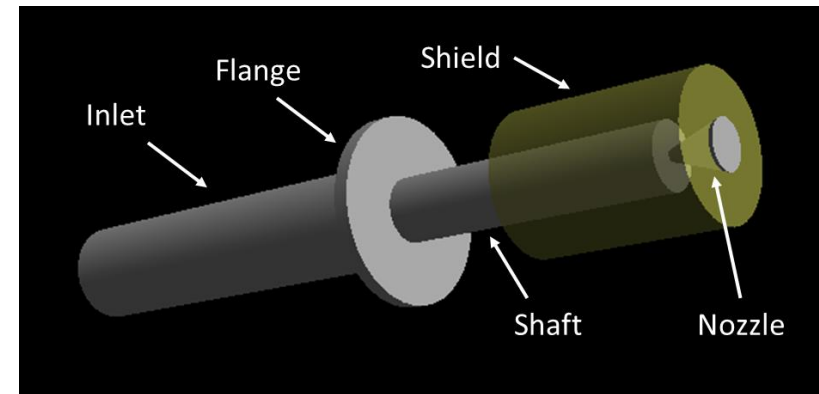
# Complete Thruster Tests

- Full Thruster (60°)
  - Early failure of lower half nozzle consistent with other tests
  - Initial opening of large inlet part
  - Significant delay for outgassing
  - Continuing demise once outgassing stops
- Thruster is less demisable than assessed in L2K



# 1N Thruster Model Construction

- Two models constructed based on Ariane component
  - 5 object connected model suitable for complex tools
  - Simplified 2 component parent-child model for DRAMA
  - Both models composed of a mixture of Haynes 25 “thin” and “thick” materials
- Complex model designed to capture test data
- Extrapolated to flight
- Evaluate simple model statistically using PADRE with both DRAMA and SAMj
- Both models added to database



# Destructive Re-entry – initial data set

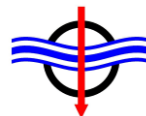
- Material models
  - All existing DRAMA models
  - All existing ESTIMATE material properties
  - Haynes 25, Hiperco
- Component models
  - All existing DRAMA models
  - SCORED 1N monopropellant thruster
  - Simple layered magnetorquer
  - Generic demisable SADM
  - Generic fill / drain valve
- Preliminary component models (not included)
  - Fibre optic gyroscope
  - 10N bipropellant thruster



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# Conclusions

- **Spacecraft Object Risk Evaluation Database**
  - Hypervelocity impact
  - Destructive re-entry
- **Database**
  - Based on Django / Python
- **Hypervelocity Impact**
  - Models for electronics boxes
  - New models for harness
- **Destructive Re-entry**
  - Existing material models
  - Existing component models derived from test data
  - New model developed for thruster
    - New test-validated material models for Haynes 25 and Inconel 718
- **Activity will Complete in 2023; Database Availability TBD**

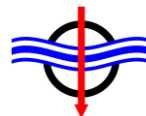


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