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SPINE metting

Etude métier: Feasibility study for the interfacing between the material data base CNES/MATREX and the Spacecraft Plasma Interactions Software SPIS

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Introduction/objectives of the study

Study of the feasibility of an interfacing between the simulation software of spacecraft-plasma interaction SPIS and the material database CNES/MATREX

- Identify interaction and usage scenarios
- Cross check the relevance of the material definitions
    - Identification of the needs of SPIS in material definition
    - Review of materials stored in MATREX from the SPIS point-of-view
- Propose possible software approaches for an integration of a MATREX client into SPIS
- Identify possible roles of a centralised material database in the SPIS's user community (academical and industrial)
- No integration / software developments targeted in the frame of the present study

Material setting: a key issue

- **Material attribution and setting is a key issue for the relevance and the accuracy of the simulations**
  - Define the boundary conditions for plasma models (e.g conductive surfaces)
  - Directly impact several of the interaction mechanisms
    - Photo-emission
    - Secondary emission
    - Sources
  - Internal electrical balance (conductivity, capacitance...)
- **Identification of the relevant material is difficult for non expert or in operational context**
- **No clear identification of referenced materials**

Current SPIS materials

- **Material available with the standard SPIS release are:**
  - Mainly issued from the late 70's (NASCAP based material) and early 2000's (ESA/ONERA works)
  - No guaranty of validation nor reference to referenced materials
  - Not taking into the last evolutions of industrial material.

0: ITOC (Material coated with ITO)
1: CERS (Solar cell material. Cerium doped silicon with MgF2 coating)
2: CFRP (Carbon fibre, conducting, no resin layer)
3: KAPT (Kapton, average values for SEE...)
4: COSR (Optical solar reflector without MgF2 coating. Cerium doped glass type)
5: EPOX (Epoxy. Thin layer of Epoxy resin on (conducting) Carbon fibre)
6: BLKP (Non conductive black paint. SEE yields are as measured for Electrodag 501)
7: BLKH (Non conductive black paint HERBERTS 1002-E. Values updated 3.10.88.)
8: BLKC (Conductive black paint Electrodag 501)
9: PCBZ (White paint PCB-Z assumed to be conductive in space)
10: PSG1 (White paint PSG 120 FD assumed to be conductive in space.)
11: TEFL (Teflon, DERTS measurements of SEE)
12: CONT (Generic Dielectric after 5 years in GEO environment.)
13: GOLD
14: SILV (Silver as from NASCAP library)
15: ALOX (Oxydized Aluminium. SEE yields from DERTS for Aluminium/Kapton)
16: STEE (Steel, SEE sigma +Emax from DERTS, curve shape from CONT material)
17: AL2K (Aluminium according to NASCAP-2k)
18: AU2K (Gold according to NASACP-2k)
19: KA2K (Kapton according to NASACP-2k))
20: TE2K (Teflon according to NASACP-2k)
21: OSR2K (OSR according to NASACP-2k)
22: BK2K (Black Kapton according to NASACP-2k)
23: SC2K (Solar Cells according to NASACP-2k)
24: NP2K (Non-conductive paint according to NASACP-2k)
25: GP2K (Graphite according to NASACP-2k)

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MATREX and its objectives

matrex.cnes.fr

•Centralised material database

- Initiated and funded by CNES
- Gathering in a normalised way validated and clearly identified materials.
  - Multi-physics data
  - Normalised material forms
  - Clear identification
- Includes advanced search capabilities
  - By physical properties
  - By references
- Includes an advanced validation process, to guaranty
  - The accuracy of stored materials
  - The uniqueness of stored materials
- Available through an interactive Web side, providing:
  - A secured access (login/password, https connexion)
  - Several level of access (groups and role based)

MATREX

Se connecter | Matrex
https://matrex.cnes.fr/?q=user
Google
matrex
cnes
Se connecter
Créer un compte
Se connecter
Renouveler votre compte
Réinitialiser votre mot de passe
Welcome on MATREX (MATerial Recording EXperience) website. The purpose of this database is to centralize information on space materials / processes. This is a collaborative tool for use by the CNES and its authorized partners (agencies, laboratories and industries concerned with space materials and processes). Its content can be enriched in with data provided by users. Access to certain data is restricted to CNES employees. This site is open to authorized persons through the creation of a personal account. This request is made by completing a form available in 'Créer son compte'. The administration of this site is provided by CNES, Technology, Materials and Processes Office located in Toulouse. For questions, please send an email to: admin.matrex@cnes.fr.
Bienvenue sur le site de MATériaux Retour d'Expérience (MATREX). L'objectif de cette base de données est de centraliser des informations relatives aux matériaux/procédés spatiaux. Il s'agit d'un outil métier collaboratif à l'usage du CNES et de ses partenaires autorisés (agences, laboratoires ou industriels concernés par les matériaux et procédés spatiaux). Son contenu peut s'enrichir au fur et à mesure des données fournies par les utilisateurs. L'accès à certaines données est réservé aux agents du CNES. Ce site du CNES est ouvert aux personnes autorisées, via la création d'un compte personnel. Cette demande s'effectue en remplissant un formulaire, accessible dans l'onglet "Créer son compte". L'administration du site est assurée par le CNES, Service Technologie, Matériaux et Procédés situé à Toulouse. Pour toute question, vous pouvez envoyer un email à : admin.matrex@cnes.fr.
Identifiant: *
Mot de passe: *

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MATREX

Search Criteria

Usual

ECSS materia

Advanced search

Identifier	Usual name
33	Kapton H
773	Kapton HN

Generals Informations | Properties | Documents

User details

User Type: CNES

Last modification date : 30/01/2014 Creation date : 21/03/2012

Risks on material

Please contact the CNES for more information

Designation

Usual name: Kapton H

Others designations:

Chemical nature

ECSS Material class: 17: Thermoplastics (e.g. non?adhesive tapes and foi

Materials family: Thermoplastic polymers

Chemical family: Polyimide (PI) (thermoplastic)

Other chemical information: Polyimide

Miscellaneous informations

Material presentation:

Film polyimide de différentes épaisseurs : 12, 25, 30, 50, 125, 250 µm (disponible pour des

General applications of the material:

- Protection, tenue mécanique des fils, réparation.

Generals Informations | Properties | Documents

Electrical | Mechanical | Physical | Space | Thermal

Propertie	Value (unit)	Visibility	Comments	Last modification date	User type	Action
Dielectric strength	276 (kV/mm)	Public	ECSS-Q-70-71A / ASTM D149-64 (25µm film @25°C)	30/01/2014 06:03:59	AUTRES	
Dissipation or loss factor (tan delta)	0.003 (-)	Public	ECSS-Q-70-71A / ASTM D150-64 (25µm film @25°C)	30/01/2014 06:03:59	AUTRES	
Electrical resistivity	1e16 (ohms.m)	Public	ECSS-Q-70-71A / ASTM D257-61 (25µm film @25°C)	30/01/2014 06:03:59	AUTRES	
Relative dielectric constant (Epsilon_r), relative permittivity	3.5 (-)	Public	ECSS-Q-70-71A / ASTM D150-64T @1 KHz (25µm film @25°C)	30/01/2014 06:03:59	AUTRES	

Methodology

- **Review of the needs of SPIS**
  - Identification of needed physics to define a material for SPIS
- **Identification of collaboration scenarios**
  - Level of integration
  - Context of exploitation
  - Security, confidentiality
- **Review and analysis of both data structures**
  - Identification of stored informations
  - Cardinality of the data structures
  - Identification of uniqueness of stored information
  - Identification of meta-data (e.g. units)
- **Review and identification of exchange formats**
  - Currently available
  - Potentially available in future evolutions
- **Identification of possible conversion bridges and bottlenecks**
- **Provide recommandations for future evolution**

Uses cases and scenarios

The level of integration and the technical solutions depends on the usage and the needs of the users.

- **Usage 1 - Store materials in MATREX (i.e. SPIS to MATREX)**
- **Usage 2 - Loading of a new material (i.e. MATREX to SPIS)**
- **Approach A - No integration, manual access and conversion:**
  - No software integration;
  - Accesses to both software manually and individually;
  - Conversion of extracted data is also done manually.
- **Approach B - No software integration / automatic or semi automatic data conversion**
  - No software integration;
  - Accesses to both software manually and individually
  - Conversion process is performed using a software procedure using exported files from MATREX and SPIS/Frida-compliant material catalogue or reciprocally.
- **Approach C - Full integration / development of a rich client integrated into the simulation software and/or IME**
  - Finest possible interfacing
  - Direct integration of a dedicated rich client inside the tailored code or IME

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MATREX data structure

- **Each material is defined by a normalised form**
  - Identification name and designation
  - Users and related groups of access
  - Several indicators on the quality/relevance/risk on the material
  - Indicate the chemical/physical nature
  - Fields for general meta-informations
    - Material presentation
    - Means of implementation
    - General applications
    - Comments
  - Several physical properties gathered by domain:
    - Electrical, mechanical, physical, space, thermal
  - Properties are characterised by:
    - A key-name, being selected in pre-defined key set.
    - A value (scalar or range)
    - A unit (string)
    - A comment
    - Traceability informations

Major limitations for SPIS evolutions (→ key-name, value)

No conversion capabilities (→ unit)

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MATREX in/out

- **MATREX exports / shows data under three forms**
  - The default html rendering, for a direct use by the user;
  - A PDF export of the equivalent data;
  - An ASCII CSV format, currently corresponding to the best basis for data exchanges with SPIS.

```
##########################
# Properties joined to this material #
##########################

"Electrical"
"Propertie";"Value (unit)";"Visibilité";"Comments";"Last modification date";"Type utilisateur";"Obsolete"
"Dielectric strength";"276" (kV/mm);"Public";"ECSS-Q-70-71A /  ASTM D149-64-(25µm film @25°C)";"30/01/2014 06:03:59";AUTRES;"Valide"
"Relative dielectric constant (Epsilon_r), relative permittivity";"3.5" (-);"Public";"ECSS-Q-70-71A / ASTM D150-64T @1 KHz-(25µm film @25°C)";"30/01/2014 06:03:59";AUTRES;"Valide"
"Dissipation or loss factor (tan delta)";"0.003" (-);"Public";"ECSS-Q-70-71A /  ASTM D150-64-(25µm film @25°C)";"30/01/2014 06:03:59";AUTRES;"Valide"
"Electrical resistivity";"1e16" (ohms.m);"Public";"ECSS-Q-70-71A  /  ASTM D257-61-(25µm film @25°C)";"30/01/2014 06:03:59";AUTRES;"Valide"
(…)
```

MATREX communication protocols

- MATREX is available under the form of a dynamic Web site.
- A user authentication by login and password is required.
- All communications and data exchanges are performed though a standard http based protocol and classic GET/ POST requests.
- Connexion and data transfers are secured (https tunnelling).

Multi-physics/multi-models contexts

- **Material definition is especially critical in case of multi-physics / multi-models approaches**
  - Uniqueness : How to define the «same» material for different models ?
  - Require a high level of expertise from the user to select the right material in different fields (e.g. plasma, radiations...).
  - Multi-physics validation process
  - Outlines several difficulties:
    - Cardinality and level of details in the material description versus geometrical definition and properties attribution
      - Quid of the impact of surface treatment ?
      - Geometrical LOD
      - Material attribution not bijective nor direct from one model to another one.
    - Identification of a (few) common exchange format(s) and conversion(s)
      - Point-to-point direct conversions implies the definition of n2 converters
      - A central, normalised and common exchange format for material properties reduces this constraint to n+1 conversion bridge
      - But bring back the difficulty into the format definition itself

Centralised material database highly relevant

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Limitations and bottlenecks (I)

- **MATREX mainly designed to be used by a human user and not directly by a tailored code as rich client**
  - This is a choice, not an intrinsic limitation
  - Still make the interfacing with SPIS more complex
    - Necessity tin «interpret data» and additional processing for tailored info
    - Limited communication protocol
- **Legacy NASCAP parameters are normally supported by MATREX, but...**
    - Only a few material provided and none of them has all NASCAP parameters filed -> Human interpretation and expertise still needed.

Limitations and bottlenecks (II)

- **Strong differences between both data structures**
  - This is the major limitation of the current implementation
  - Formalism of MATREX induces
    - A predefined and fixed set of properties

➡Limits the evolutions of SPIS where new properties may be added according to the evolutions of SPIS kernel

    - Only scalar values (and ranges) are currently supported

➡Forbid the integration/use of new additional parameters with series, matrices and tabulated values

➡Possible workaround using free fields in MATREX (e.g. comments) or linked document, but we lost the advantage of the formalism

Limitations and bottlenecks (III)

- **Limitations of the communication protocol and access**
  - Currently only based on http/https communication (GET/POST methods)
  - Only a light client (Web) available
  - No rich communication API, like Web services, provided currently
  - No TK available for the development of rich clients
- **Limitation of the current exchanges formats**
  - MATREX
    - Current ASCII export format
      - Not hierarchized
      - Nor real anchor/mark to identify sections and fields
      - No control of the format (e.g. no XSD rules, no version number)
  - SPIS/Frida
    - XML based and hierarchised
    - Not fully stabilised
    - No clear separation between generic and tailored informations
    - No traceability
    - Sustainability not guaranteed yet

Limitations and bottlenecks (III)

- **Limitations in the access control, security and confidentiality**
  - Limited number of groups of user -> Only one common «SPIS users» group
  - Constraint for industrial actors
- **Naming, status and traceability in SPIS/Frida**
  - Normalised naming and uniqueness
  - Data status
  - Validation process
  - Traceability
- **Volume of exchanged data and performances issues in the future**
  - Might be critical in the future with tabulated data

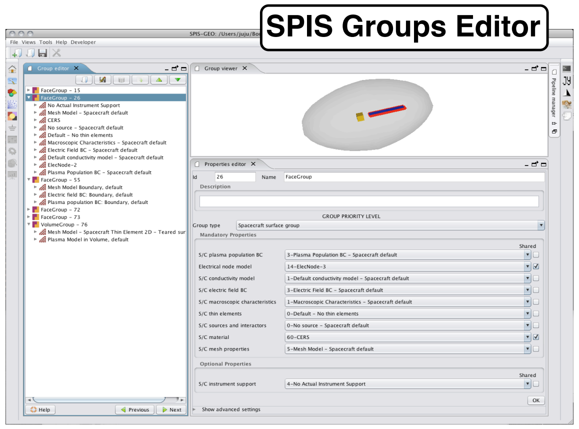
Propositions of improvements and evolutions

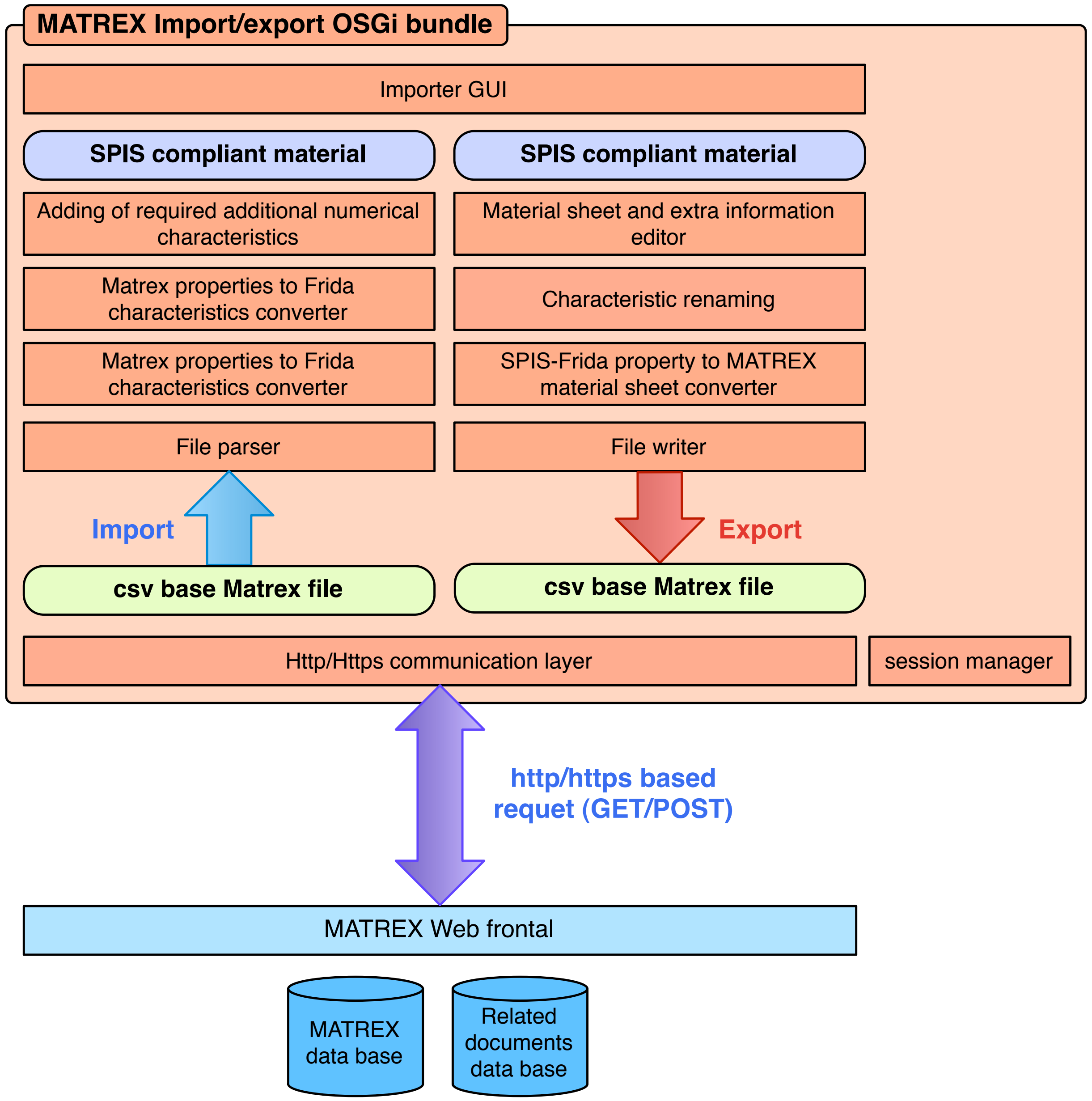
- **Design proposition for an import/export module from/toward MATREX in SPIS**
  - Fine integration (scenario C)
  - Two technical alternatives
    - Http based communications
      - No impact on MATREX
      - Limited approach
      - Costly reverse enginiering on the client-side

➡Shall be considered as a workaround ?

    - Web services based alternative
      - Much more powerful
      - Require extension of MATREX (exposed API)

➡Standard approach





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Propositions of improvements for MATREX

- **Extension of the data structure**
  - Support series and matrices
  - Possibility to consider the time evolution of material characteristics
- **Improved / finer cardinality in stored data and/or LOD capabilities**
  - E.g. access to properties in its own not only as material
  - Have a various level of material descriptions (including tailored parameters)
  - Inheritance and object oriented approach
- **Web exposition and/or richer communication protocol**
  - Introduction of a richer control API exposed as Web Services
    - SOAP
    - XML-RCP
- **Improved interoperability layer and exchange formats**
  - CSV based format too limited
  - Normalised format recommended (e.g. CDF, XML based, STEP-NRF based)
  - Structured and hierarchized format
- **Distributed design and interconnected network of material databases**
- **Finer and adaptable access rules**

Possible improvements in Frida

- **Introduction of meta data to indicate the validation level of stored data**
- **Introduction of the possibility to define validation processes, especially for the tailored layer of handled data (i.e. check if the imported/exported data are fully self-consistent for SPIS);**
- **Introduction of a better traceability and naming rules for stored data;**
  - Author and validator names
  - Normalised reference/name
- **Better handling and conversion of units;**
  - Conversion capabilities (introduction of UOMO)
- **Better conversion capabilities of data and LOD.**
  - Possibility to extract sub-set

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Conclusion and recommendations (I)

- **A centralised material database like MATREX is highly relevant for space environment applications, especially in:**
  - An industrial context and use by non-experts
  - A multi-physics / multi-model approach
- **May constitute at term a reference point for material definition in space application**
- **An fine interfacing of MATREX with SPIS seems possible but complex in the present state and with limited fonctionnalities**
- **A «light integration» (approach A) is still recommanded for now**
- **The current data structure of both, MATREX and Frida, present strong limitations and (at least partial) refactoring seems needed to address all the relevant physics.**

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Conclusion and recommendations (II)

- **Before all new software developments a deep user requirement analysis should be done, especially in multi-physics context and to take into account the evolution of models**
  - Identify data to be stored and with which formalism
  - Identify the structure of stored data (e.g. scalar, vector, range, series...)
  - Identify the related meta-data (e.g. error bars, units, names, comments...)
  - Provide a richer conversion facilities for units
  - Provide several Level of Detail (LOD) and finer cardinality to access to stored data from different «point of view»
- **Network of databases**
- **Identify or define a central and richer exchange format**
  - Structured
  - Normalised
  - Adopted by several community
  - Providing tools and rules to check its own consistency
  - Check the capabitliies of existing formats (CDF, XML, STEP....)
- **Strongly recommend to coordinate this effort with other equivalent activity at ESA (Interop, CIRSOS...) and in the industry**