Second SIP Caravan

# Structural Materials for Innovation (SM⁴I)

SIP-SM⁴I
Structural Materials for Innovation

## - Tough, Light and Heat Resistant Materials for Aircrafts -

SIP

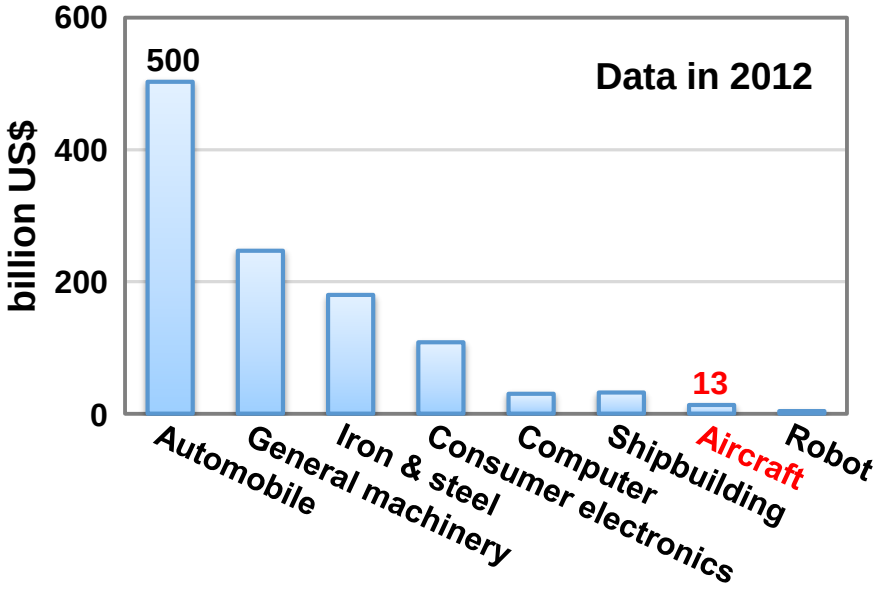
Strategic Innovation Promotion Program

**Prof. Teruo KISHI**

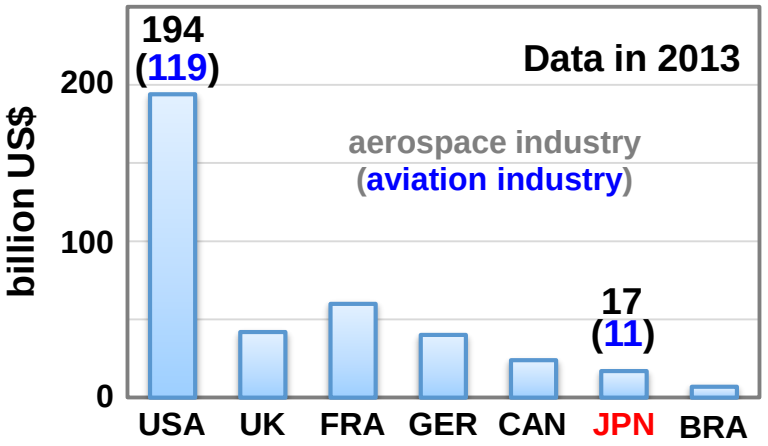
**Program Director, CAO**

# Background: Aviation Industry in Japan and World

## Industries in Japan

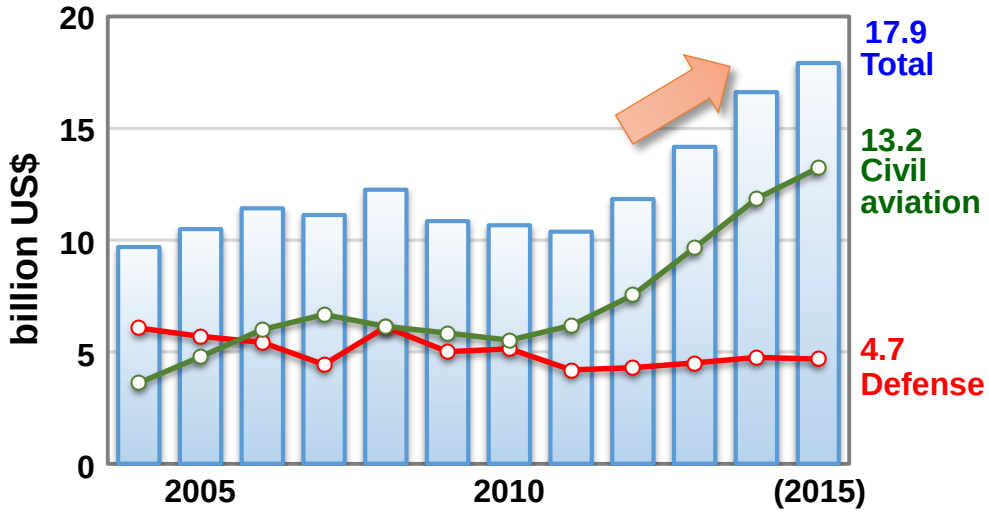



## Comparison to other countries




**Ref)** Report by The Society of Japanese Aerospace Companies.
Aerospace Industries Association of Brazil

## Aviation industry in Japan




**Japanese aviation industry is small because of historical reason.**

**However, Japanese materials science and industry are strong.**

**Japanese aviation industry has a big potential to develop more.**

# Structural Materials for Innovation (SM$^4$I)

**【Program Director】 Teruo KISHI**

Professor Emeritus, The University of Tokyo;
Former President, NIMS;
Advisor to the Ministry of Foreign Affairs of Japan

- ✓ Development of tough, light-weight and heat-resistant structural materials applicable to aircraft and power generator
- ✓ Encouraging Japanese aviation industry
- ✓ Improvement of the energy efficiencies for saving energy and reducing $CO_2$ emission

**【Duration】 Five years (2014 – 18)**

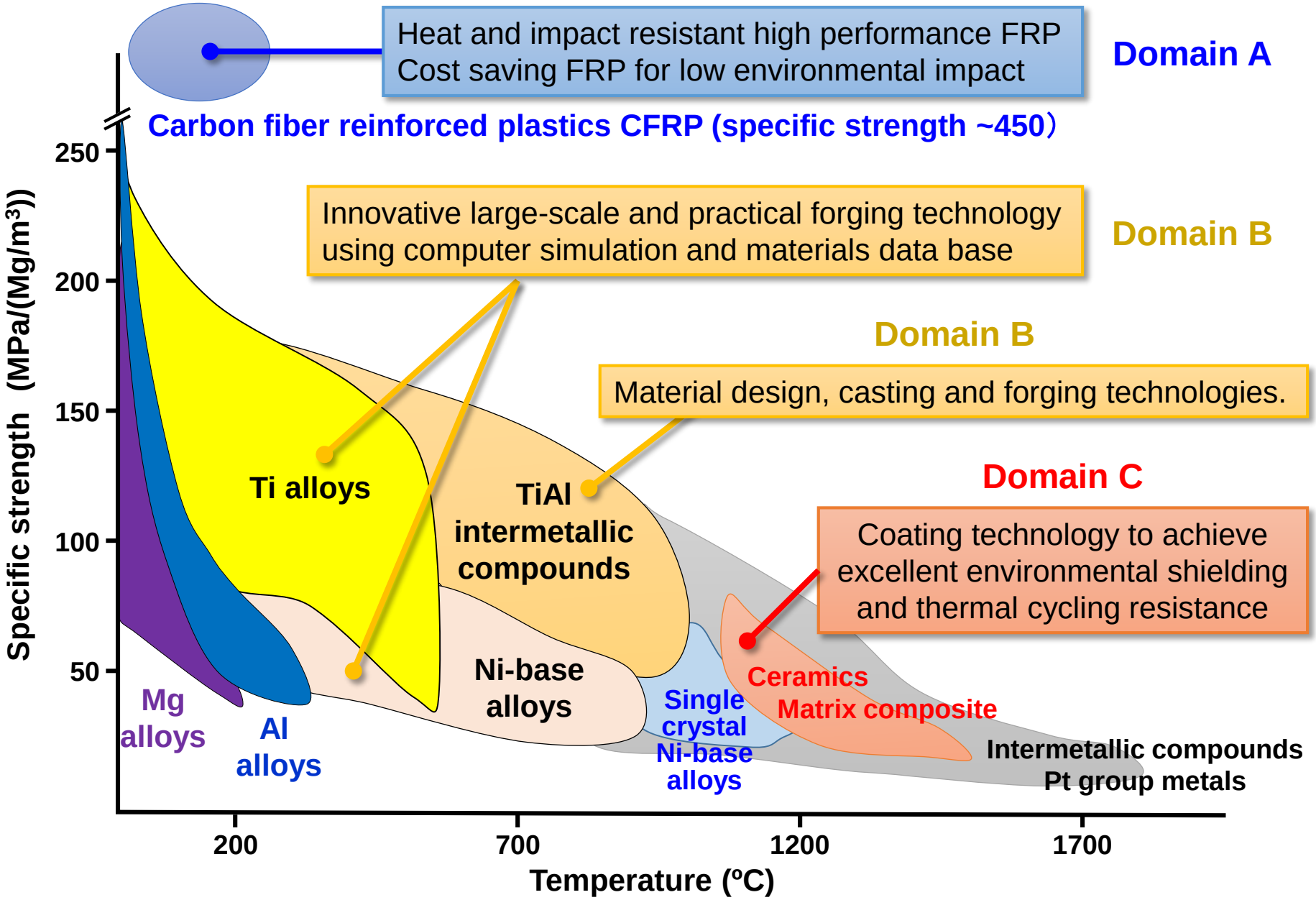
**【Budget】**

| FY | Total (US$) |
|---|---|
| 2014 | 36.1 million |
| 2015 | 38.8 million |
| 2016 | 37.6 million |

**Composition of SM$^4$I (2016)**

- **Industry: 31**
- **University: 37**
- **National/Public Institutes: 10**
- **Total: 78**

# Properties of Heat Resistant Materials



# Structural Materials for Innovation

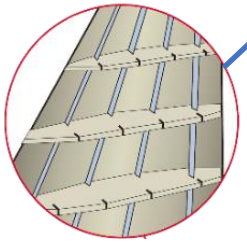
## (A) Polymers and FRP

**A11** Main structure

**A02**

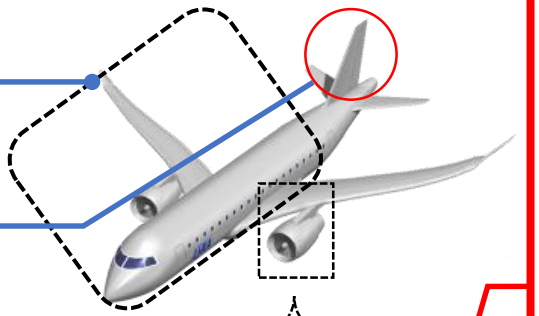
**Out-of-Autoclave CFRP**

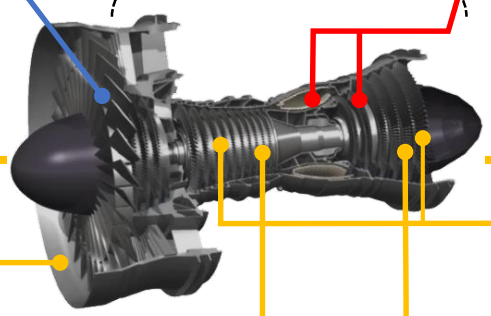
Tail skin (Main structure)



**A01** Fan blade

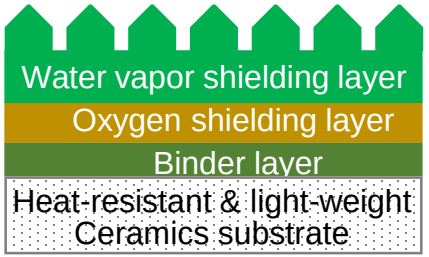
**Thermo-plastic resin CFRTP**





## (C) Ceramics coatings

Thermal shock absorbing layer




**C41-43**

Combustion chamber
High pressure turbine

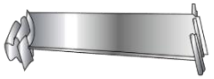
## Ti Alloys

**B22**

Fan case

**Laser power metal deposition**

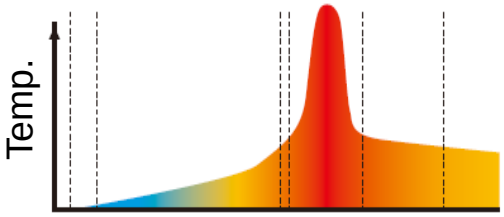
## TiAl intermetallic compounds



**B29-31**

Low pressure turbine

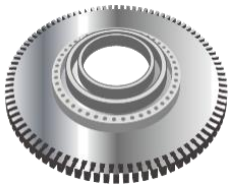
High pressure compressor




## Ti and Ni-Based Alloys

**B23**

Compressor Turbine stator vane



**B21**

Compressor Turbine disk

## (B) Heat resistant alloys and intermetallic compounds

# Materials Integration (MI)

**Aims** **Reducing R & D time and cost, reducing diagnosis and maintenance cost, application for certification (virtual testing).**

(A) Polymers & FRP

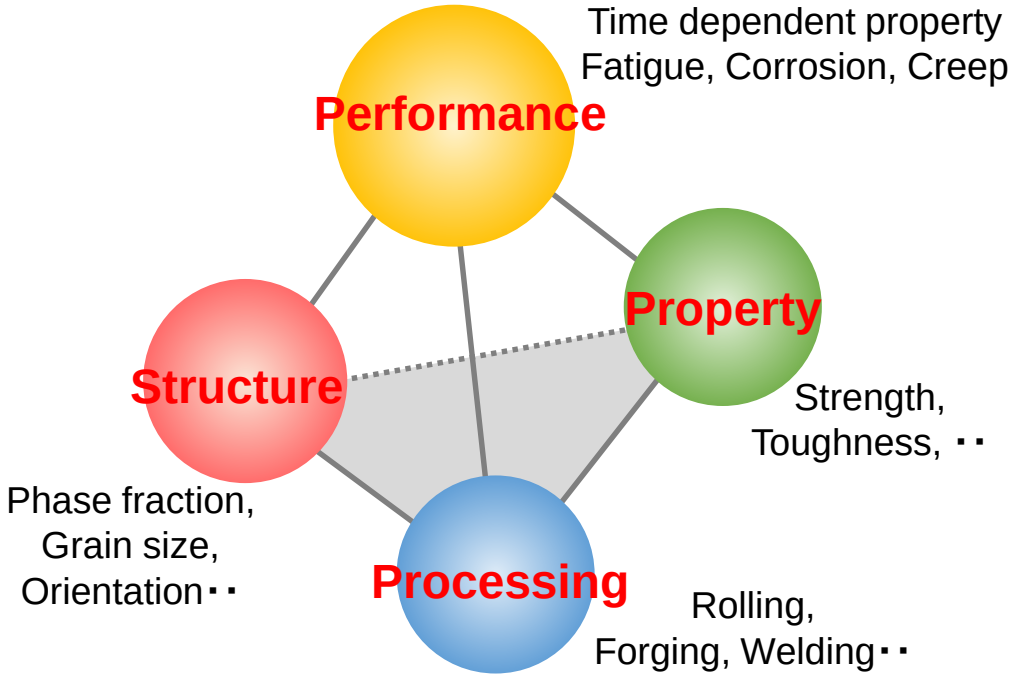
(B) Hear resistant alloys & Intermetallic compounds

(C) Ceramics coating

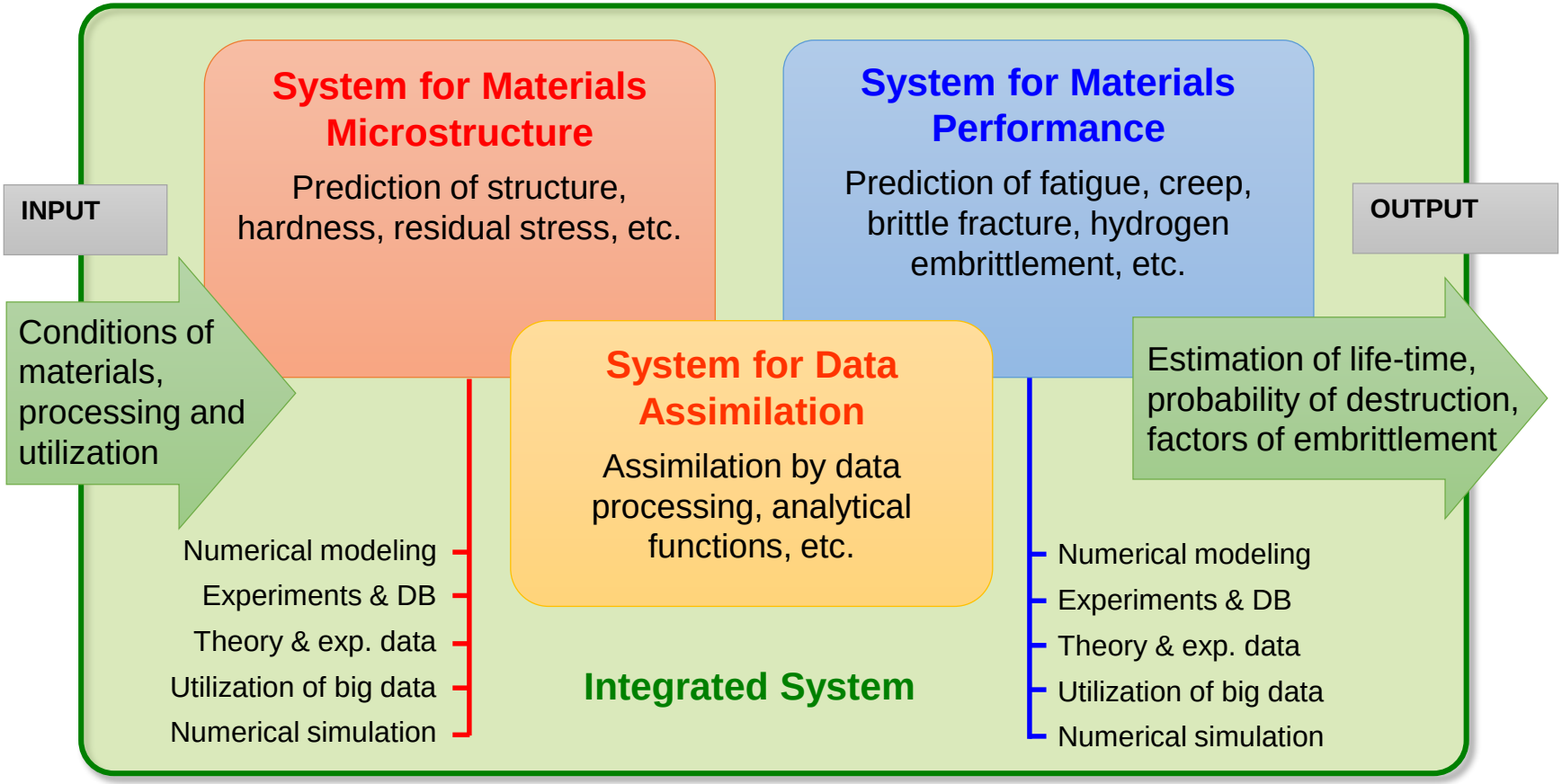
(D) Materials Integration (MI)

**Integration of**

- **Theory**
- **Experiments**
- **Instrumental analysis**
- **Simulation**
- **Database**
- **Informatics**



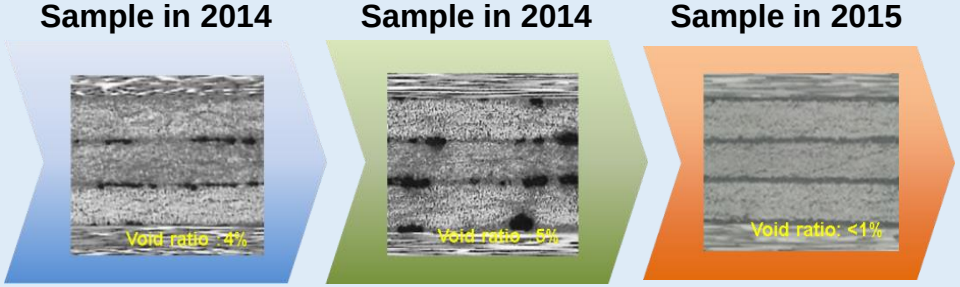
# Materials Integration




| Processing | Structure | Property | Performance |
|---|---|---|---|
| Casting | Phase fraction | Stress-strain | Fatigue |
| Rolling | Precipitation & growth | High temperature strength | Creep |
| Forging | Grain size distribution | Fracture toughness | Hydrogen embrittlement |
| Welding | Hardness distribution | Hydrogen diffusion | Brittle fracture |

# Representative Results

## (A) Out-of-autoclave CFRP




**Clear midterm target values (Void ratio < 1%, CAI > 40ksi).**
**Same performance as sample prepared using autoclave.**

**Develop low-cost CFRP manufacturing technology**

CAI: Compression after impact

## (B) Forging simulator (1.5 kt)
## (Working at NIMS from May 2016)


**Preparation of materials database for forging process.**

**Optimization of forging process condition before utilizing 50 kt-press machine. (Japan Aeroforge, Kurashiki).**

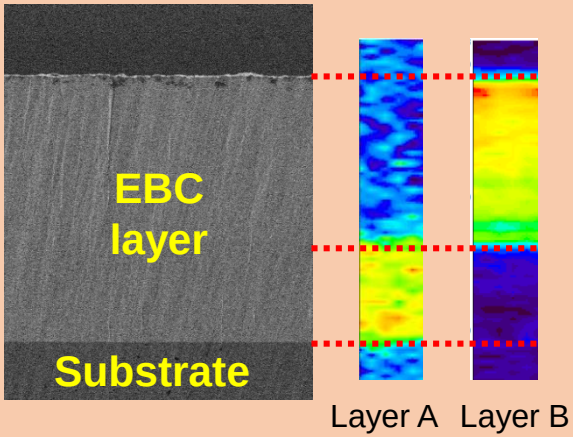
**Saving time and cost of R & D.**

## (C) Environmental barrier coating (EBC)

**High-quality EBC coating technology was established.**

**High damage tolerance at 1400$^0$C**

**Development of more efficient jet engine**



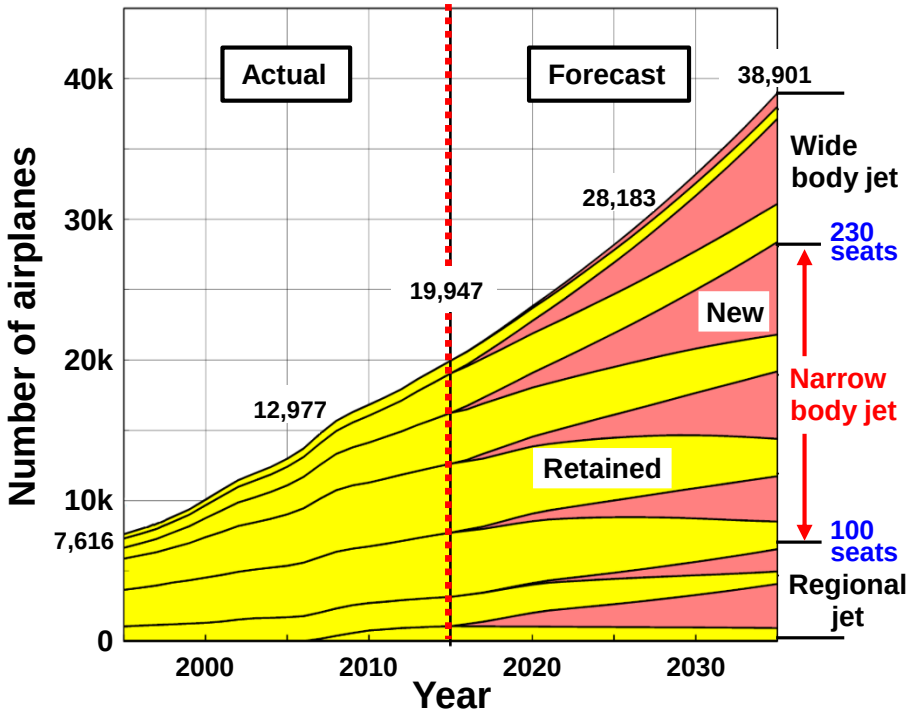
# Growth of Aviation Industry driven by SM⁴I

We are developing innovative structural materials applicable to narrow body jet (volume zone) developed after 2030.

Number of narrow body jet

13,084 (2015) ⇒ 21,839 (2035)

## Fleet development of passenger jet




| Domain | Projects (module) | Production in 2030 |
|---|---|---|
| (A) FRP | Out of autoclave (Tail skin etc.) | 1.8 billon $ |
| | Thermoplastic resin (Fan・Case) | 1.6 billion $ |
| | CFRP (Main body) | 13 billion $ |
| (B) Metals | Ti, Ni-based alloy (Turbine stator vane) | 4.8 billion $ |
| | TiAl intermetallic comp. (HPC etc.) | 3.1 billion $ |
| (C) Ceramics | CMC (HPT etc.) | 2.2 billion $ |
| Total | | 26 billion $ |

**Ref)** Worldwide market forecast 2016-2035 Japan Aircraft Development Corp.

Ref) Report on business strategy of structural materials for innovation (2015)

# Establishment of Centers of Excellence

## for Sustainable Structural Materials R&D in Japan

SIP-SM4I Structural Materials for Innovation

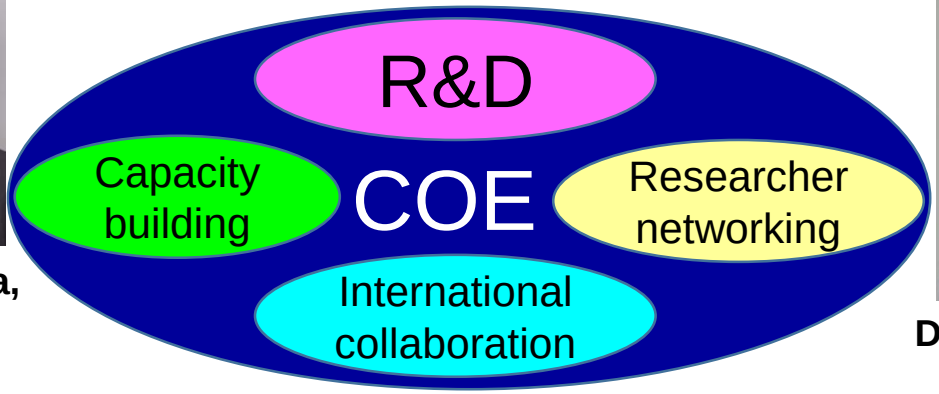
### Domain A: CFRP

**Univ. of Tokyo &**

**JAXA (Japan Aerospace Exploration Agency)**

- Monitoring, modeling & simulation
- Performance evaluation

**Prof. N. Takeda, U. Tokyo**




### Domain B: Alloys

**NIMS (National Institute for Materials Science)**

**& TITECH (Tokyo Institute of Technology)**

- Alloy design
- Processing
- Performance evaluation

**Dr. Y. Mitarai, NIMS**

**Prof. M. Takeyama, TITECH**

### Domain C: Ceramics Coatings

**JFCC (Japan Fine Ceramics Center)**

- Coating design & processing
- Performance evaluation

**Prof. M. Takata, JFCC**

### Domain D: Materials Integration

**Univ. of Tokyo & NIMS**

- Computational materials science
- Database
- Informatics
- MI system

**Prof. T. Koseki, U. Tokyo**

# Peer Review of Project

Advisory board gives comments and suggestions for new theme assignment and evaluation of the results.

## Domestic advisory board

Meeting frequency: Three times in 2015
Two times in 2016

Board member: Akira AZUSHIMA (Chair)

| Sector | Number | Affiliation |
|---|---|---|
| **Academic** | **5** | |
| **Industry** | **5** | **Nippon Steel & Sumitomo Metal** |
| | | **Toyota** |
| | | **Mitsubishi Heavy Industry** |
| | | **Japan Airlines** |
| | | **All Nippon Airways** |
| **Government** | **1** | **Japan Aerospace Exploration Agency (JAXA)** |
| **Total** | **11** | |

## International advisory board

- 2-3.Mar.2016
  @International House of Japan, Tokyo

- 25.June.2016
  @Hotel Bristol Vienna
  Prof. M. Van de Voorde (EC)
- 29.June.2016
  @Federal Institute for Materials Research and Testing (BAM), Berlin
  Prof. T. Boellinghaus (Germany),
  Dr. A. Laukkanen (Finland),
  Prof. L. Schalpbahch (Switzerland),
  Prof. K. Potter (UK)

# Outreach Activities

- SM⁴I made brochures to introduce our mission.
- We regularly publish magazines to report our recent activities.
- We utilize internet and SNS to post the latest news.

## Brochures and magazines


**Short version for all domains (JPN・ENG)**

**Full version for each domain (JPN・ENG)**


**SIP-SM⁴I MAGAZINE (JPN)**

## Japanese Science and Technology Policy toward Innovation

### First overseas outreach “Caravan”

Japan-Germany Rectors’ Conference
Time: June 28, 2016, 17:30～18:00
Venue: Japanese-German Center Berlin

**Japanese science and technology policy toward innovation**
Cabinet office Counselor
**Jun IWAMATSU**

**SIP project “Structural materials for Innovation”**
Science and technology advisor to the Ministry for foreign affairs of Japan
**Prof. Teruo KISHI**

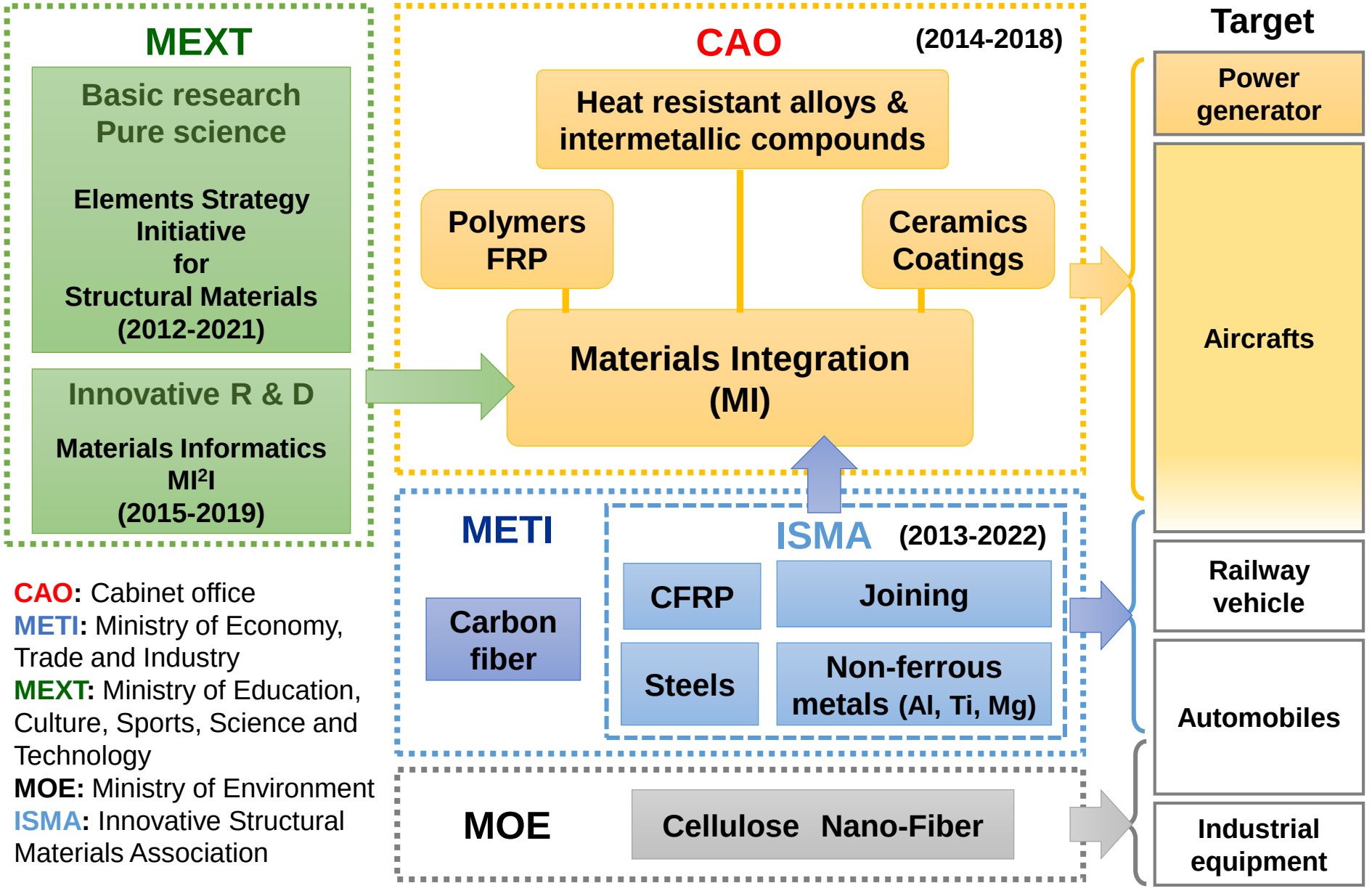
CAO MOFA


## Internet & SNS

- **Open original HP of SM⁴I**
- **Introduction of young researchers via Facebook.**

**http://www.jst.go.jp/sip/k03/sm4i/index.html**

# National Projects for Structural Materials in Japan




**CAO**: Cabinet office
**METI**: Ministry of Economy, Trade and Industry
**MEXT**: Ministry of Education, Culture, Sports, Science and Technology
**MOE**: Ministry of Environment
**ISMA**: Innovative Structural Materials Association

***Thank you very much for your kind attention!***

『革新的構造材料』

***Structural Materials for Innovation (SM$^4$I)***

SIP-SM$^4$I

Structural Materials for Innovation