3rd EGATFL Meeting
3rd-5th March, 2015
OECD/NEA HQ, Paris

UPDATE ON SIC/SIC PROJECTS IN OASIS

Akira Kohyama
OASIS, Muroran Institute of Technology

Collaborators at OASIS:
Hirotatsu Kishimoto, Joon Soo Park, Naofumi Nakazato,
Daisuke Hayasaka, Yuuki Asakura, Chisato Kanda

MEXT PROGRAM ON "INNOVATIVE NUCLEAR R & D"

The Sub-title has been changed from 2012:
"Basic Technology Development for Nuclear Safety Innovation"

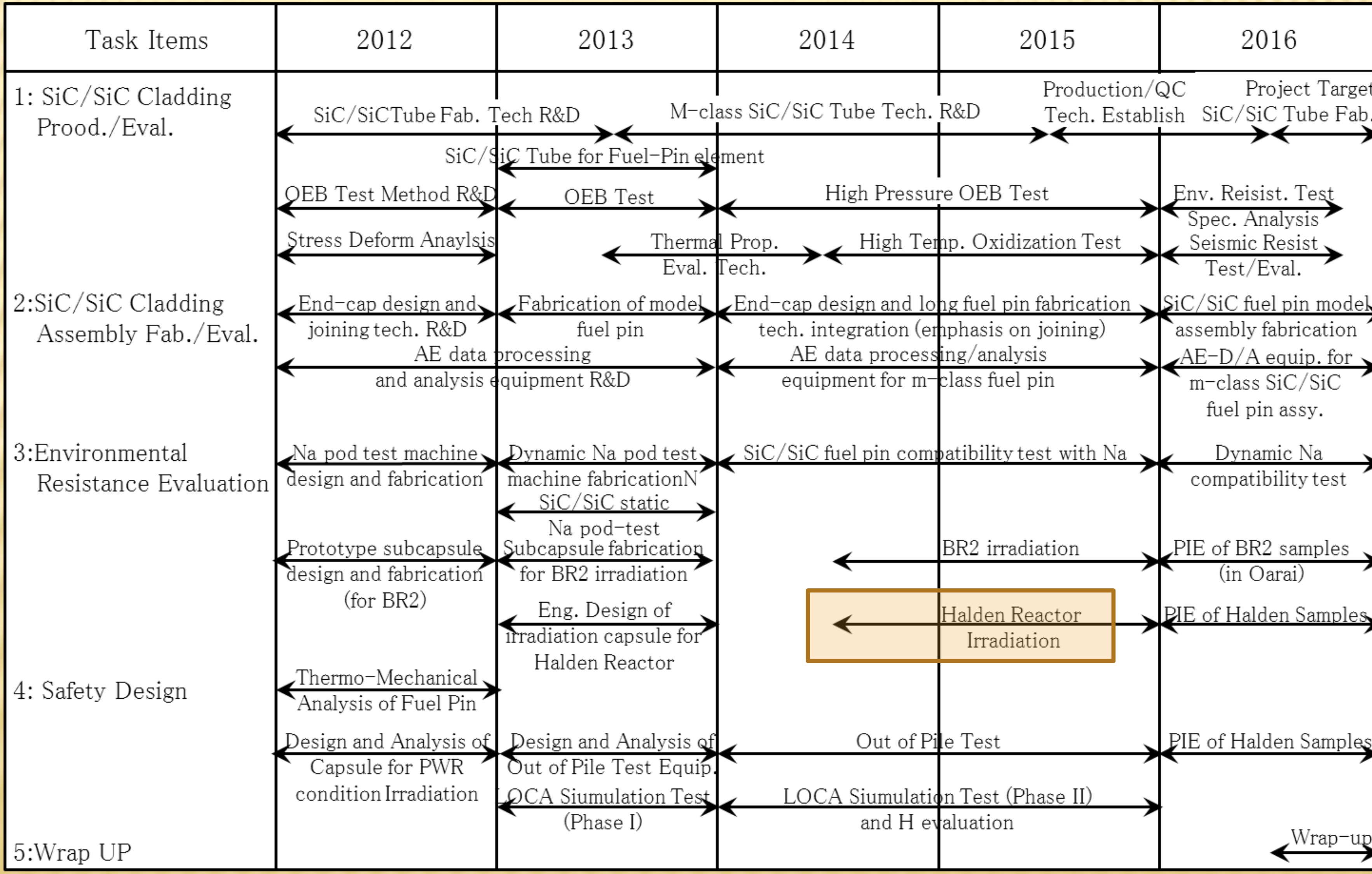
◆R & D of Basic Fabrication Process Technology of SiC/SiC Fuel Clad for Extra-Safe Reactor Core

1: Proof-of-the-reality of SiC/SiC Fuel Clad as a replacement of Zircaloy Clad.
2: Feasibility Demonstration of SiC/SiC Fuel Clad for LWRs, SFR and GFR.

◆Establish large scale production basis of SiC/SiC Fuel Clad by NITE-Method[1), 2)].
◆Integrate technologies of making SiC/SiC Fuel Pin and Fabricate Fuel Pin Segment for Reactor Irradiation.
◆Evaluate Properties of SiC/SiC Clad, SiC/SiC Fuel Pin, up to 1 meter, including environmental tolerance evaluation under light water reactor and LMFBR.

(1): Japan and International patent by A. Kohyama and Y. Katoh
(2):Current SiC clad fabrication process is advanced NITE ptocess, "DEMO-NITE Process"

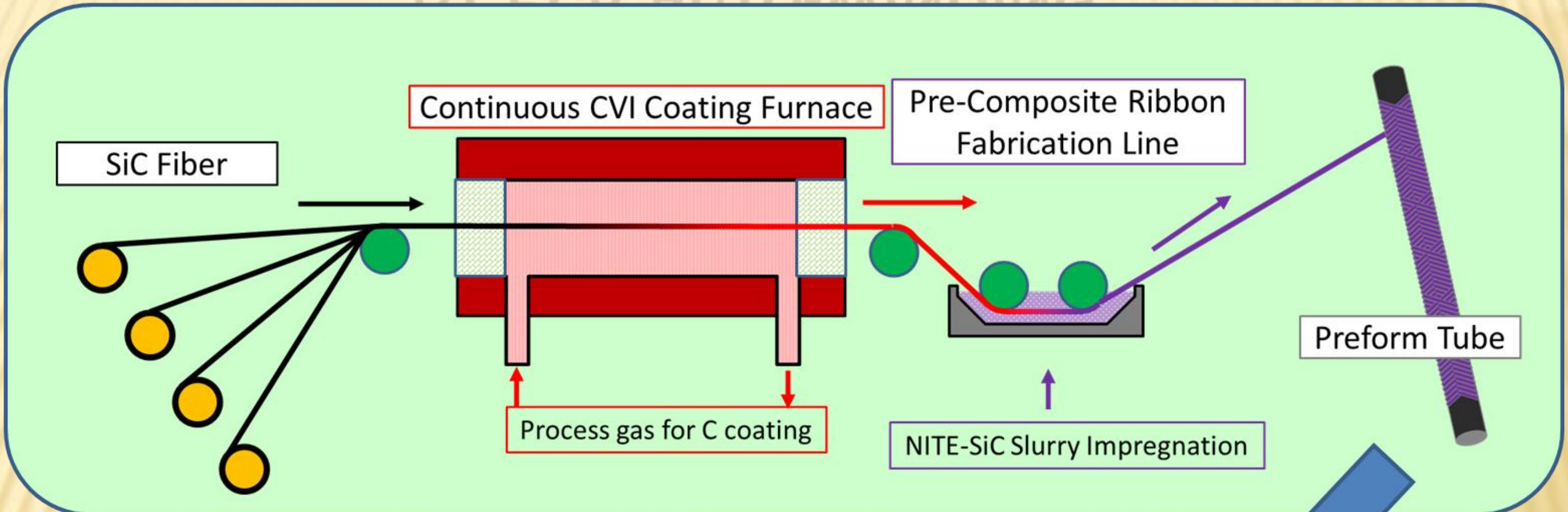
"SCARLET" PROJECT PLAN

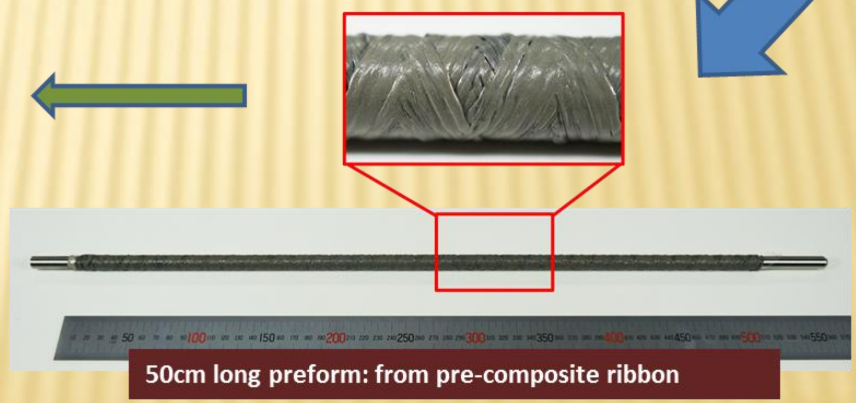


REACTOR IRRADIATION ON SIC/SIC CLADDING R & D

	Encapsuled		Water Loop		Status
	Vac./He	H_2O	PWR	BWR	
1. Coupon Irrad.	○	○			JMTR/JOYO/HFIR/FFTF/ EBR-II/BR2/BOR60
2. Clad/Cut-out Irrad.	○	○			
3. Clad Irrad.	○	○			
4. Clad (open end) Irrad.			○		MITR Experiment *(ref. D.M. Carpenter, MIT)*
				○	
5. Clad (with Zircaloy end caps) Irrad.			○		SCARLET-at Halden
				○	
6. Clad (with Zircaloy end caps and fuel) Irrad.			○		
				○	(INSPIRE-at Halden)
7. LTR Irrad.			○		*(SCARLET-Phase2)*
				○	*(INSPIRE-Phase2)*
8. LTA Irrad.			○	○	

DEMO-NITE PREFORM TUBE BY PCR AUTO-WINDING

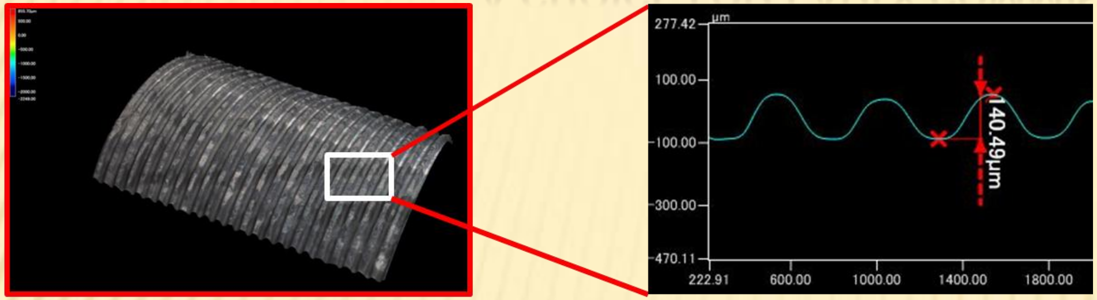




Long SiC/SiC preforms (500mm) will be processed by large scale HIP facility in March 20, 2015.

ZIRCALOY + SIC/SIC JOINT TEST SAMPLE

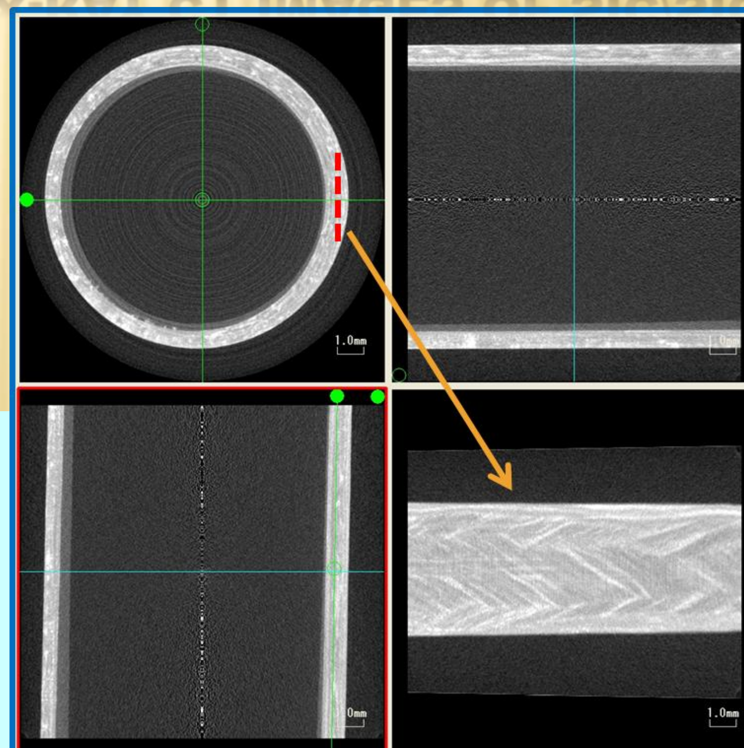
-A CHOICE FOR EARLY COMMISSIONING -



10mm^{id}, 0.7mm^{t} NITE-SiC/SiC Tube

Zircaloy End-cap SiC/SiC Cladding

X-RAY CT IMAGES OF SIC/SIC



He Leak Tightness of SiC/SiC and Its Joint with Zircaloy:

He leak rate:

Required for Halden Reactor: $<1\times10^{-9} P_a m^3/sec$

The champion data: $<1\times10^{-11} P_a m^3/sec$

mostly: $1\times10^{-10} P_a m^3/sec$

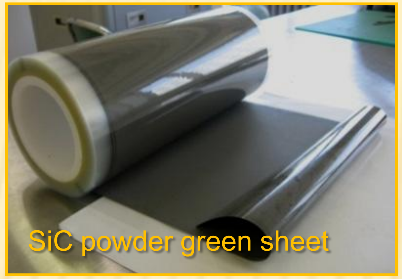
(this value is equivalent with Zircaloy cladding)

A. Kohyama: Organization of Advanced Sustainability Initiative for Energy System/ Material, Muroran Institute of Technology

MAKING BREAKTHROUGHS UNDER OASIS PROJECTS

- TECHNOLOGY AND RESOURCE FOR SIC/SIC -


CVD coating device at OASIS


SiC powder green sheet

Material Resources for OASIS

- Fibers: Cef-NITE production has reached the ability over 1 ton/year from 2008.
- Woven fabrics production (1.5m width) has been started since 2008.
- Coatings: Continuous and large-scale R&D has just started in OASIS.
- SiC/SiC Composites: Cera-NITE is commercially available.


NITE SiC/SiC with Zircaloy segments for Halden Reactor irradiation

The Current Technologies

- Large-scale supply capability of advanced intermediate materials for SiC/SiC:
  Green sheets, Prepreg sheets, PCR, etc.
- Automated/continuous fabrication technology for long SiC/SiC tube (SCARLET)
- Near-net shaping of ATF components with helium gas leak tightness (SCARLET and INSPIRE)
- Brazing and Joining for SiC/SiC segment and ATF components
- Reactor irradiation technology of SiC/SiC segments with/without nuclear fuels under LWRs. (SCARLET and INSPIRE)

THE 1ST SCARLET SEGMENT IRRADIATION AT HALDEN

The first SCARLET segment irradiation test in IFA-775 at Halden commenced on December 22, 2014 and continued until February 1, 2015. (37days)

- *The reactor has been operated under stable conditions at a thermal power level of approximately 18-18.5 MW.*
- *The reactor was shutdown for unloading/loading of test rigs on January 29, 2015.*

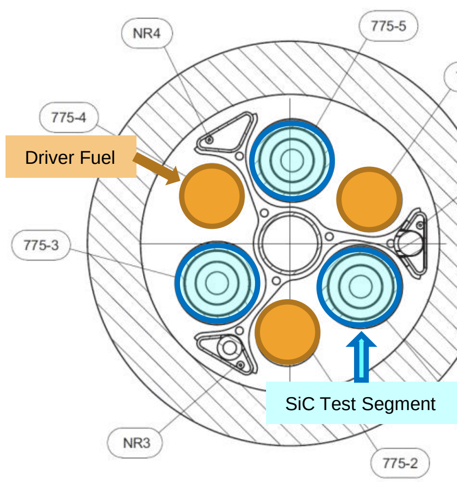


Figure 1. Cross-section of IFA-775 and pressure flask ILS-364.

The rig was connected to Loop 6 (light water high pressure loop system) operating under representative PWR conditions.

- Coolant inlet temperature : 270-290 ° C
- Coolant outlet temperature : 285-310 ° C
- Loop pressure : 162±2 bar
- Flow rate (flow velocity) : 1600±30 litre/hour

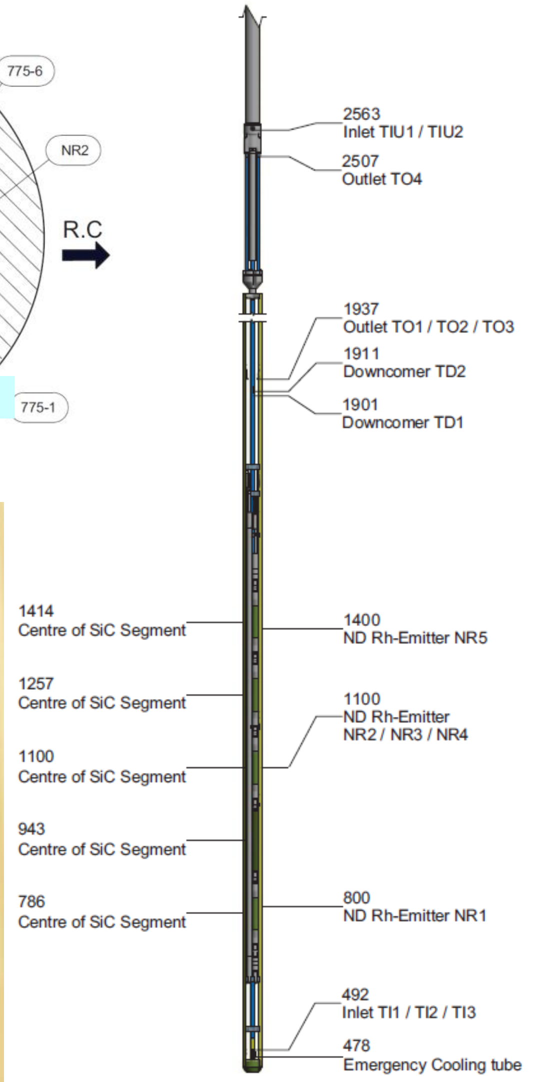
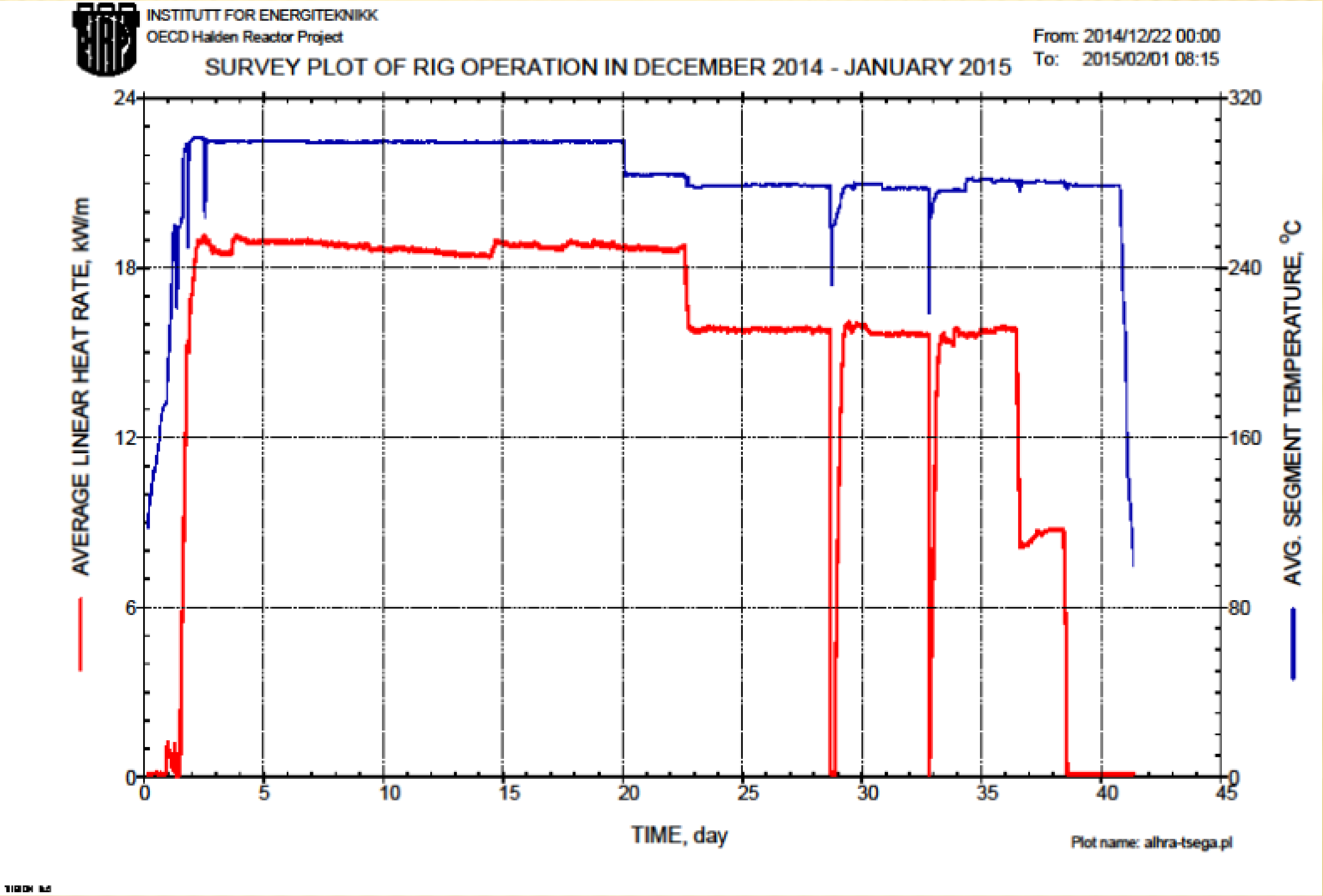


Figure 2. Axial position of SiC segments and instruments in IFA-775.

SURVEY PLOT OF RIG OPERATION AT HALDEN



METI PROGRAM FOR "ENSURING NUCLEAR SAFETY TECHNOLOGY"

Baseline Concept：

Replaceable SiC/SiC clad from Zircaloy cladding is to be developed. Thus the specification is aimed to satisfy ASTM Standard B 353－91, for LWR.

SiC/SiC clad by NITE-process; $10mm^{id}$, $1\ mm^{t}$ and $200mm^{l}$.

Dimensional Accuracy:

Diameter: ±0.05mm Straightness:1/1200 Wall Thickness: ±10%

Roundness: 1/2000 (Accomplished)

Baseline Mechanical Properties：

Axial Tensile Strength:300MPa, Hoop Strength: $100MPa^{(Comp)}/300MPa^{(Tens.)}$

Fracture at accident: no straight/ crystallographic through thickness fracture (>0.2% Pseudo-plasticity）

Environmental Resistance：

Out-of-reactor Oxidization test, LOCA simulation test：

Better than Zircaloy.

Neutron Damage Resistance：

1）Soundness check up to 10GWd/t exposure at Halden Reactor under BWR water condition.

2）Confirm mechanical property degradation less than 5% at BR2 reactor irradiation.

THE CURRENT PROJECT PLAN (APRIL 1, 2014)

Task Items	2012	2013	2014	2015	2016
1:Ceramic Fuel Pin Fabrication Modification and Technology Integration	Sample Prep. For BR2 Irrad.	Plate Sample Fabrication.	NITE Sample Fab.	Baseline Prop. Eval.	Fuel Pin Fab. And Perf. Ver.
		Fuel Pin Element Fab.	Comp. Test Fac. Design and Fab.	Comp. Test under BWR Condition	
	Fuel Pin Fabrication	Halden Irrad. Segment Fab.	Fuel Pin Develop.(1)	Fuel Pin Develop.(2)	PIE
2:Stability of Ceramic Fuel Pin Element under BWR Condition	Capsule Design	Capsule Fabrication	Halden R. Irradiation (Preparation)	Halden R. Irradiation	PIE
3:Neutron Irradiation Effects of the NITE-SiC/SiC	BR2 Capsule Design & Fab.	End-cap Joining Tech. Integration	Capsule Fabrication		
			BR2 Irrad.	PIE	
4:Wrap UP					Reporting

METI PROGRAM ON "ACCIDENT TOLERANT FUEL"

Domestic Back-up Activity connecting with:
ATF task of
"Civil Nuclear Energy Research and Development Working Group; CNWG"
Under bi-lateral commission between US-Japan

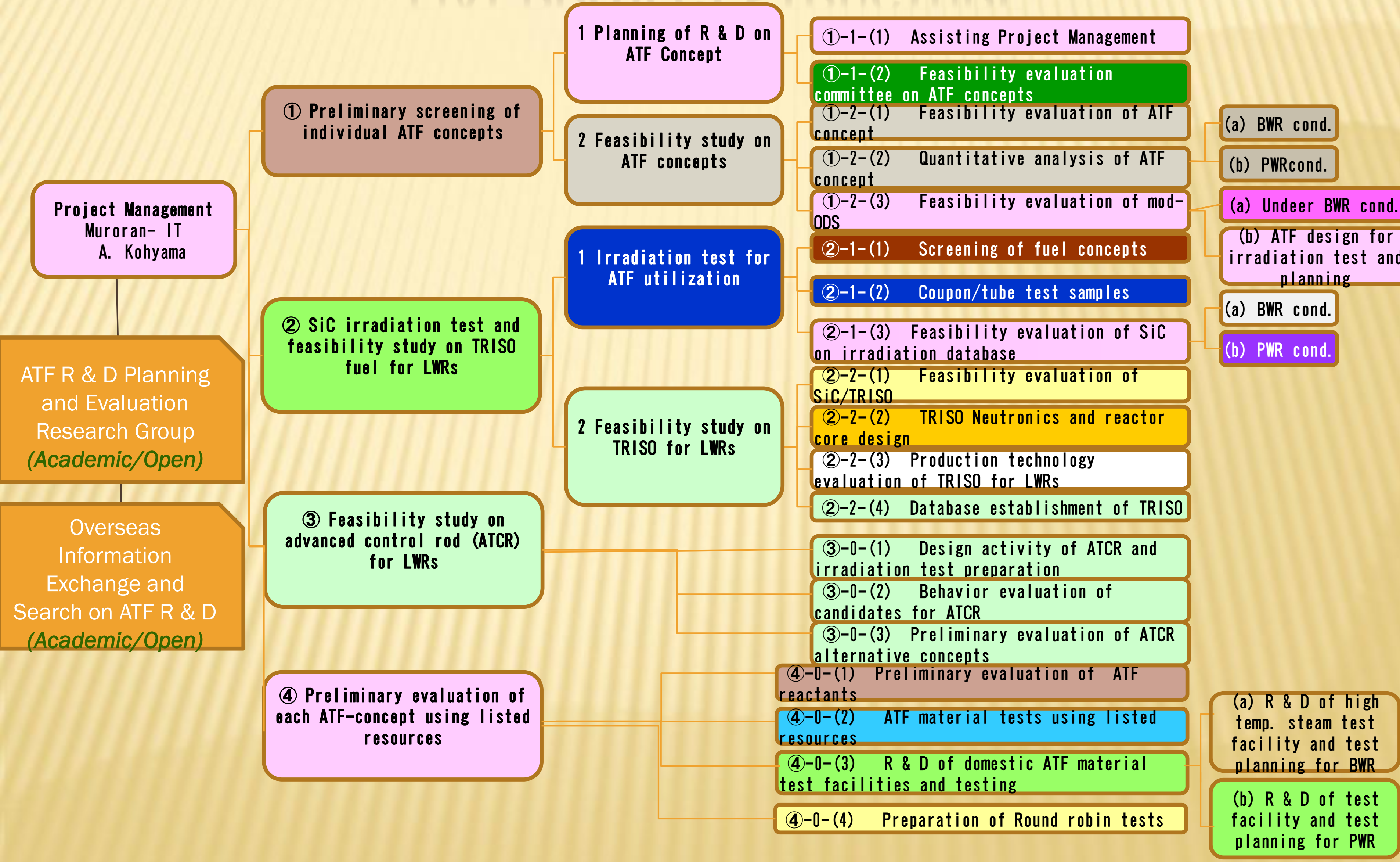
Goal: By 2022, develop and test, in an existing LWR, an advanced fuel rod which tolerates loss of active cooling in the core for considerably longer time period than existing fuel.

Objectives:

- *Significantly reduce or eliminate hydrogen generation*
- *Reduce spent fuel volume through increased burnup*
- *Reduce Fuel Pin Failures & Increased reliability*
- *Improve Economics & Permit Power Upgrades*

From DOE Document

FIAT PROJECT STRUCTURE



SUMMARY

- SCARLET, INSPIRE and FIAT projects have been continued as planned.
- The first HBWR water loop test at Halden of SiC/SiC fuel pin segment (un-fuelled) was finished for the first reactor cycle irradiation under PWR condition.
- The first HBWR water loop test at Halden of SiC/SiC fuel pin segment (fuelled) under BWR condition is at the final preparation stage.
- The first year of FIAT project is going to be finished by providing report to METI.