Aims and Scope of the European Integrated Tokamak Modelling Task Force

Howard Wilson

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Deputies: P. Strand and H. Wilson

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EFDA(03)-21/4.9.2 (June 24th, 2003) Executive summary:

The aim of the task force is to co-ordinate the development of a coherent set of validated simulation tools for the purpose of benchmarking on existing tokamak experiments, with the ultimate aim of providing a comprehensive simulation package for ITER plasmas.

The remit of the Task Force would extend to the development of the necessary standardized software tools for interfacing code modules and for accessing experimental data.

In the medium term, this task force's work would support the development of ITER-relevant scenarios in current experiments, while in the long term it would aim to provide a validated set of European modelling tools for ITER exploitation

Status and Plans in a nutshell

- The first year has been devoted to planning
  - Input from over 100 Task Force members from 23 institutions
  - Work to be organised into 7 projects:
    - The Code Platform Project (CPP)
    - The Data Coordination Project (DCP)
    - Five Integrated Modelling Projects (IMPs)
  - Plans will be submitted to STAC for approval on 30 Sept, 2004
    - On approval CPP, DCP and IMP#1 (on equilibrium and linear MHD stability) will be launched, to serve as test cases
    - A Call to Participate will be made to Associations to staff and lead these
    - Assuming they then operate successfully, the other IMPs will be launched during 2005

What does "integrated modelling" mean?

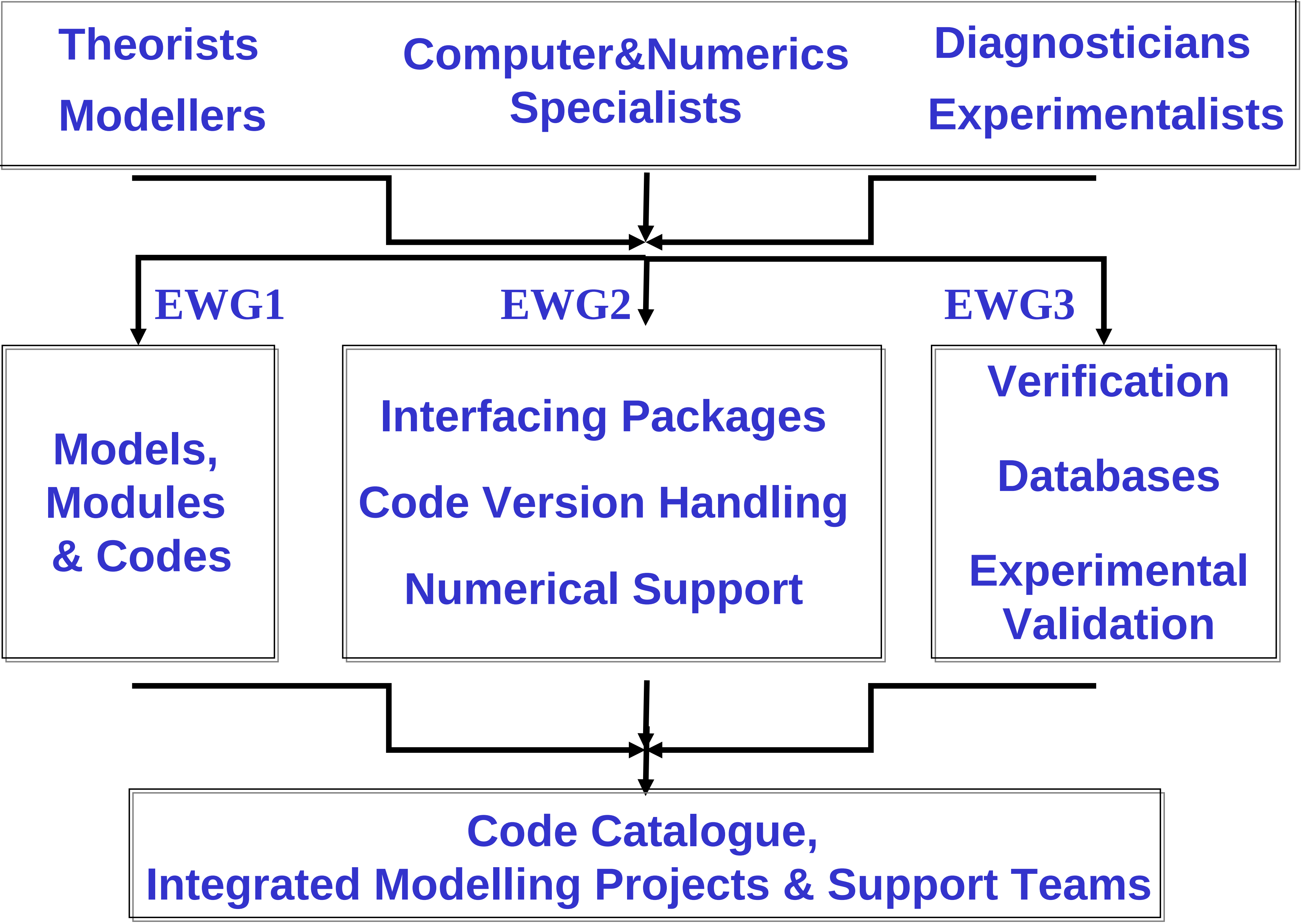
- Physics Integration:
  - Integration of MHD, transport, exhaust, energetic particle physics, etc
  - Need to foster interactions between different physics areas
- Code Integration:
  - Creating a set of validated, benchmarked codes
  - Standardised inputs/outputs to allow modules from different codes to be linked
  - A standardised framework for code development
- Discipline Integration:
  - Success of the TF relies on cross-discipline interactions, with input from:
    - Theoreticians to build/improve the appropriate mathematical models
    - Modellers/computational scientists to construct efficient, accurate codes
    - Experimentalists to provide data to validate models.
  - Involvement of each community will be important for the success of the TF

The first year's work: the planning stage

- The first year's work was developed within three "areas"
- Area 1: Identification of codes and models (Howard Wilson)
  - Take an initial census of codes and classify them
  - Identify a number of "Integrated Modelling Projects" and develop them
- Area 2: Interfacing procedure and numerical support (Alain Becoulet)
  - Evaluate the present numerical expertise and hardware within EFDA
  - Propose the global structure of integrated modelling
  - Develop the interfacing procedure
  - Identify a code version handling procedure
  - Make recommendations for language, libraries, etc
  - Develop the necessary numerical tools

The first year's work: the planning stage (2)

- Area 3: Code validation and benchmarking (Par Strand)
  - Determine the validation process (the procedure and documentation)
  - Develop an appropriate database for the validation procedure
  - Make recommendations for validation experiments
  - Provide a priority list for code integration (common task with Area 1)
  - This process will provide/test physics understanding for existing data


Theorists
Modellers
Computer&Numerics
Specialists
Diagnosticians
Experimentalists
EWG1
EWG2
EWG3
Models,
Modules
& Codes
Interfacing Packages
Code Version Handling
Numerical Support
Verification
Databases
Experimental
Validation
Code Catalogue,
Integrated Modelling Projects & Support Teams

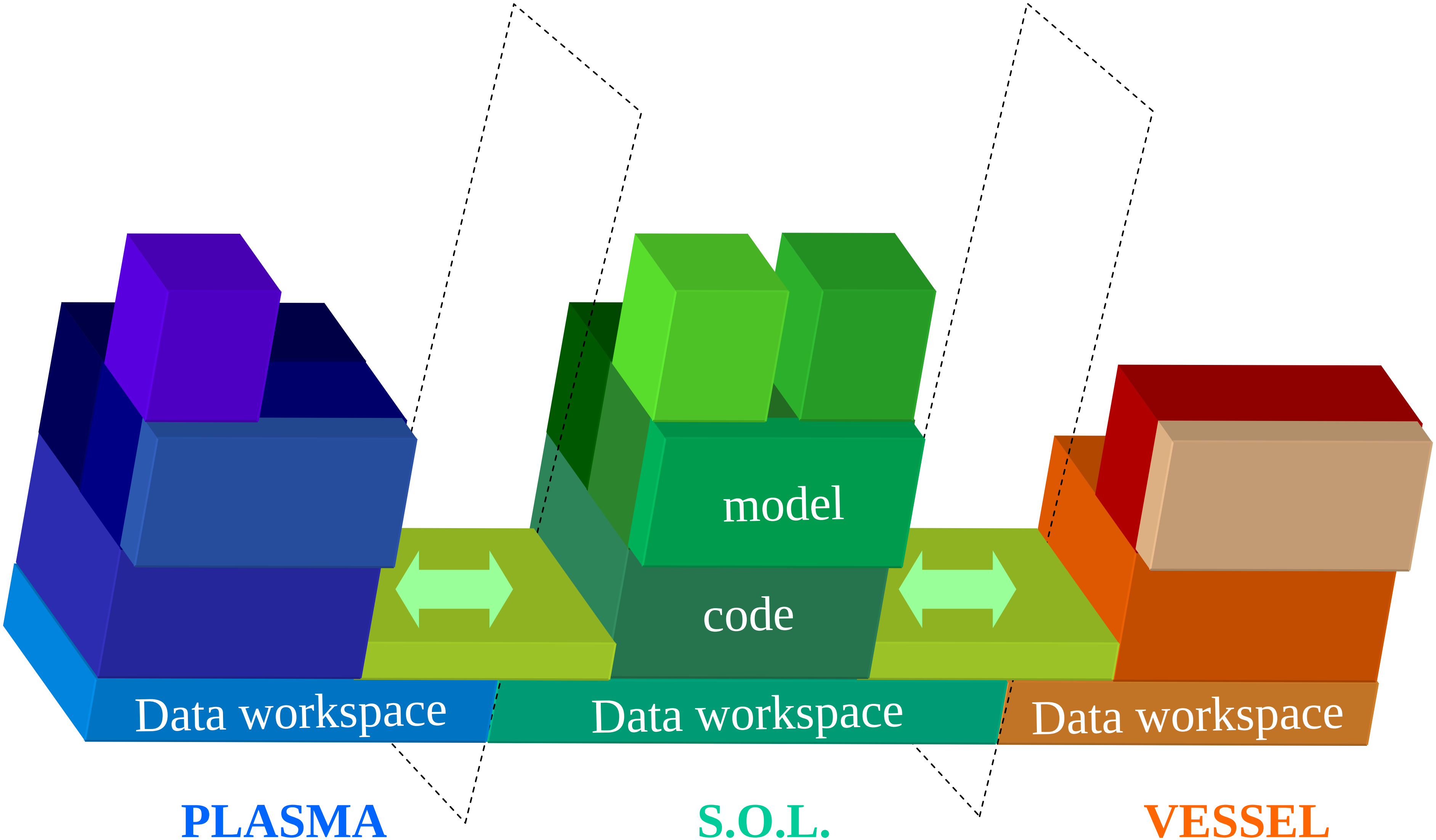
The outputs: code catalogue

- An initial assessment of the existing codes has resulted in the "code catalogue"
  - Task Force members provided a 1-page summary of codes they have an interest in
  - These were then categorised and placed on the ITM-TF web site.
  - The idea is just to indicate what is available in the community
    - not to provide detailed documentation
  - The catalogue is incomplete, but will be constantly updated as entries are provided (to me)

The outputs: The support projects (1)

- The Code Platform Project (developed from Area 2 activity)
  - Where possible, existing codes will be dismantled to form a suite of modules
  - The code platform will provide a framework into which modules will be "plugged" to provide a purpose-built code
  - The platform will also aim to provide
    - simulation data storage and retrieval facility
    - help with preparing input filesmonitoring a simulation run
    - Checking self-consistency of chosen modules
    - interfaces with actual (and planned) machine geometry (coils, H&CD systems, etc.)
    - interfaces with databases
    - diagnostics codes to interpret experimental data, to aid tests of code predictions with data

The Modular Code Platform Structure



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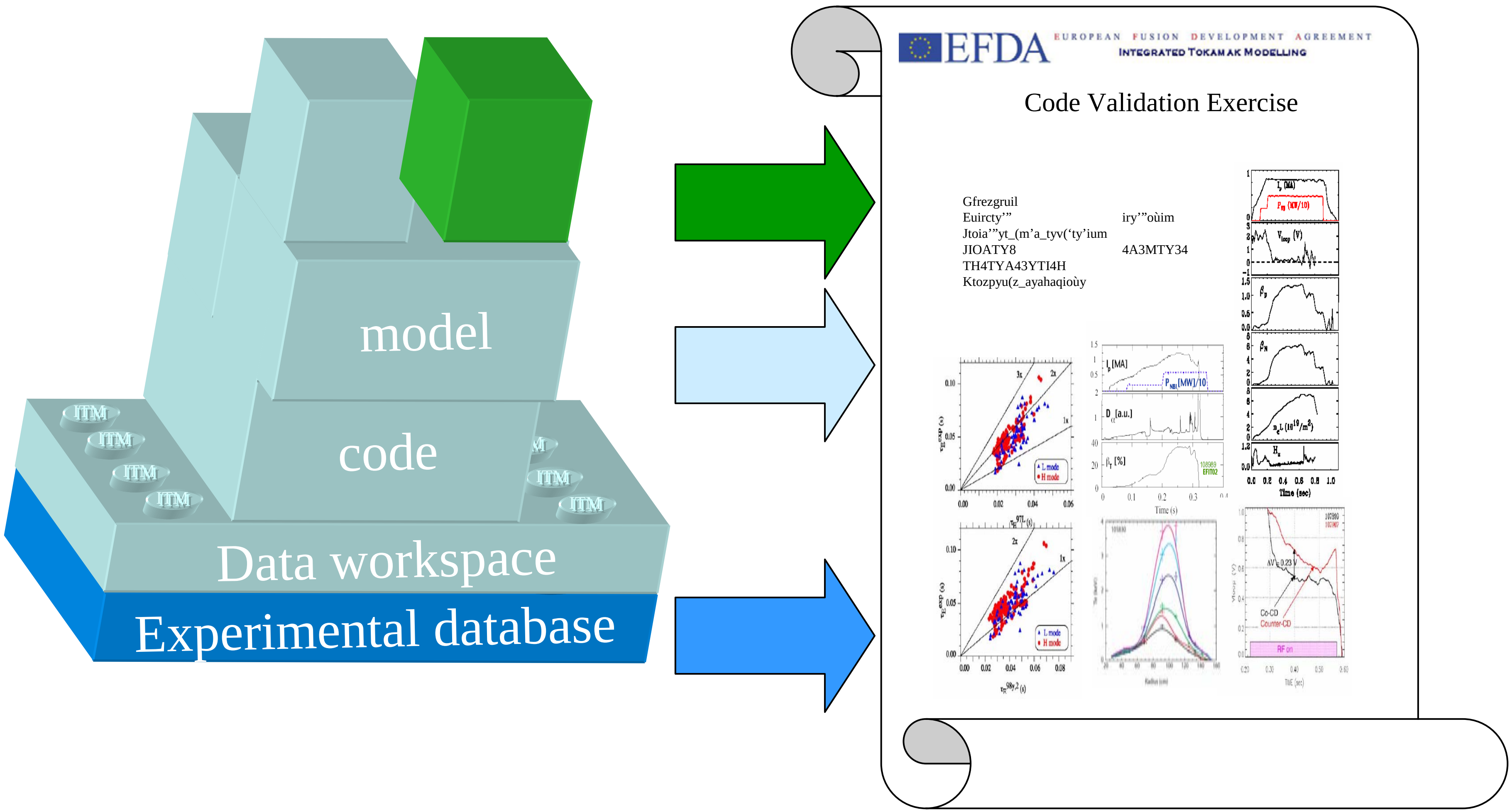
The outputs: The support projects (2)

- The Data Co-ordination Project (developed from Area 3 activity)
  - Responsible for
    - developing the tools for data access
    - developing and managing the databases required for the Task Force activities
- Main elements of the project:
  - Universal access layer
    - Software providing access to databases (remote and local)
    - Must be developed consistent with the code platform
    - Could ultimately incorporate data processing software
  - Data and database management
  - Emerging technologies
    - eg assess grid technology approaches for data sharing

Code Validation and Benchmarking



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The outputs: The Integrated Modelling Projects (1)

- Equilibrium and linear MHD stability
  - Experimental equilibrium reconstruction codes
    - standardise such codes
    - standardise input data format and links to equilibrium geometry
    - develop extended equilibrium reconstruction models (eg rotation effects)
  - Equilibrium codes and linear MHD stability
    - High precision equilibrium codes for refining experimental reconstructions
    - Standardised, validated linear ideal MHD stability codes
    - Extended linear MHD stability codes (resistive, 2-fluid, etc)
    - Identify experimental benchmarks (eg triggers for MHD events)

The outputs: The Integrated Modelling Projects (2)

- Non-linear MHD and disruptions
  - To develop models for a range of non-linear MHD phenomena:
    - ELMs, including heat loss to SOL and subsequent heat loads
    - NTMs, including threshold, mode rotation, trigger, control, etc
    - Resistive wall modes, including rotation, feedback stabilisation, etc
    - Sawteeth, including trigger, crash and impact on confinement
    - Locked mode threshold
  - To model the disruption process:
    - The quench phase
    - Halo current fraction and distribution
    - Runaway electrons

The outputs: The Integrated Modelling Projects (3)

- Transport code and discharge evolution
  - To provide a modular core transport code, with modules for:
    - transport equation solvers (diffusive and “avalanche” processes)
    - sources and sinks
    - MHD phenomena
  - To provide a modular SOL/edge transport code
    - Flexible cross-field transport capability (diffusive, “blobby”, etc)
    - Sources/sinks
    - Plasma-wall interactions
    - Stability
  - Integrated discharge evolution
    - Core-edge integration through “pedestal” region (eg transition from 1D to 2D)
    - Full discharge evolution, including plasma control system

The outputs: The Integrated Modelling Projects (4)

- Transport processes and micro-stability
  - Linear micro-stability
    - Validate existing codes (eg test for “profile stiffness”)
    - Extend models to assess importance of additional phsyics
  - Plasma turbulence
    - Benchmark different codes against each other
    - Use output to suggest appropriate turbulence diagnostics to test codes
    - Explore mechanisms for transport barrier formation
    - Address the pedestal region, and core-edge integration
    - Model impurity and helium ash transport
  - Neoclassical transport
    - Validate and extend existing models for transport, currents and flow damping
    - Provide models for drifts in SOL

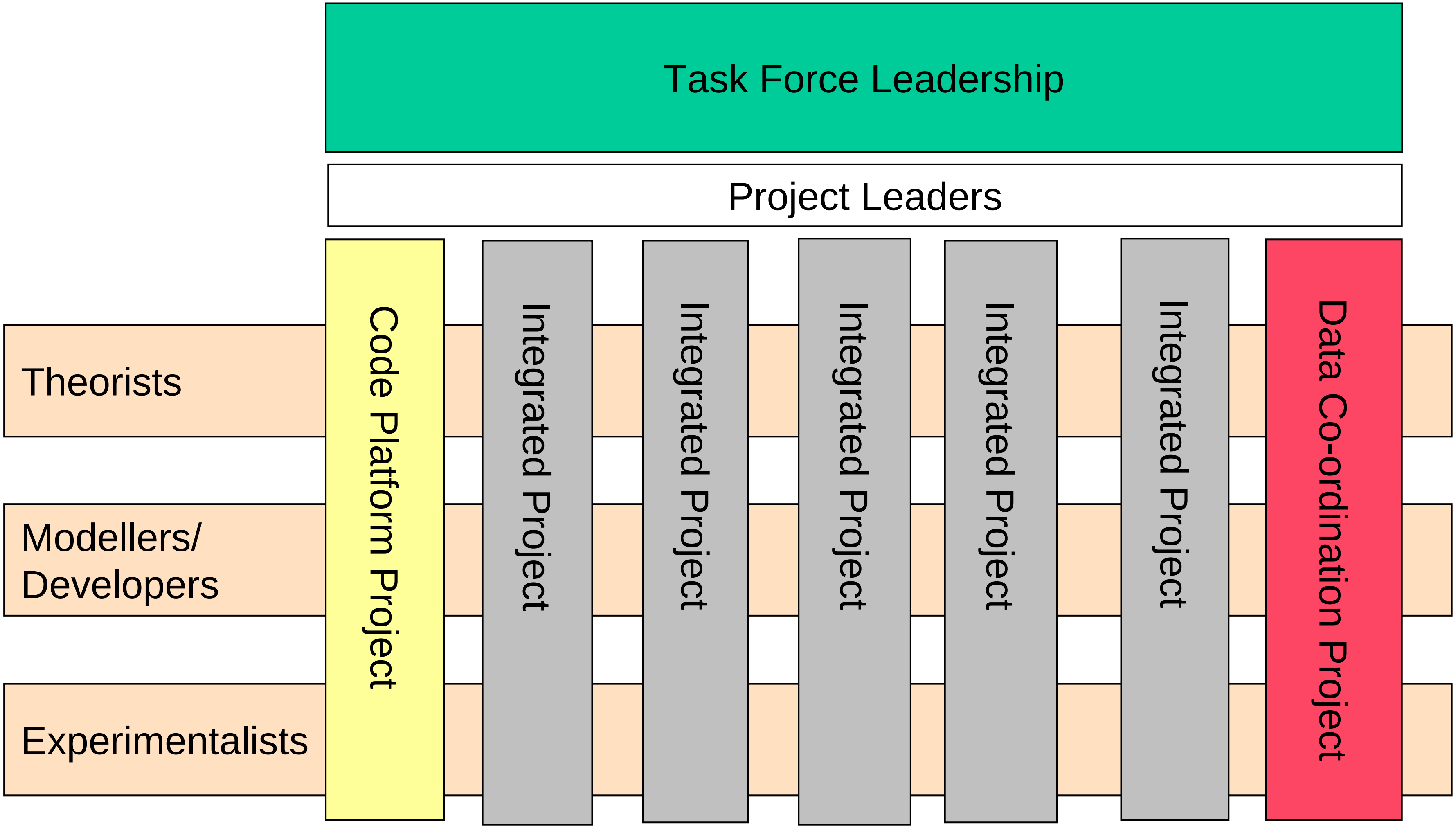
The outputs: The Integrated Modelling Projects (5)

- Heating, current drive and fast particles
  - Heating and current drive
    - Validate existing codes against experimental data and each other
    - Couple codes to explore synergistic effects between different schemes
    - Extend codes to deal with non-stationary, 3-D situations, eg for instability control
    - Extend and validate antenna codes (coupling rf to plasma, eg with ELMs!)
    - Model torques due to NBI and/or rf schemes
  - Fast particle instabilities and losses
    - Test codes against data and each other (including proposing expts)
    - Assess the impact of fast ptcles on large-scale MHD (NTMs, sawteeth, etc)
    - Fast particle losses (direct orbit loss, including ripple, and MHD-driven losses)

How will the work proceed?

- The work will be conducted under EURATOM general support
- Advantage:
  - We can get up and running very quickly
- Disadvantage:
  - Motivating people to join
- TF must bring benefits to members:
  - Crucial to address physics issues as soon as possible
  - Bring benefits to experimentalists by providing models to explore physics
  - Bring benefits to modellers by providing access to data to test models
- The process will be tested by launching 3 projects as “test cases” in October (assuming STAC approval)
  - The CPP, DCP and IMP#1 (equilibrium and linear MHD stability)

The Anticipated Task Force Structure



Collaborative activity

- There are a number of related initiatives, both in Europe and world-wide, where collaboration is important:
  - Related JET activity, including TF-T, Integration of transport and MHD codes at JET
  - The “sister” EU task force on plasma-wall interactions
  - ITPA groups
  - ITER team
  - Other integrated modelling initiatives in the US (eg, the Fusion Simulation Project, FSP) and Japan (TASK)
  - Collaborative satellite meeting at IAEA Fusion Energy Conference
  - We can also learn from integrated modelling activity in other fields (eg weather forecasting, nuclear safety, etc), which we are exploring with help from EIROFORUM.

Summary

- The work is about to begin to lay the foundations for what is to come in future years to provide a set of modelling tools
  - to interpret and develop ITER-relevant scenarios on existing tokamaks
  - ultimately, to help the EU gain maximum benefit from ITER
- Although the work is “voluntary”, there has been an encouraging initial response
- A main aim of the Task Force is to provide a framework to co-ordinate existing activity and add value by encouraging collaborative projects, not to generate additional work
- The Task Force must not lose contact with the physics; this is crucial to its success