Fusion: the clean energy source for the third millennium

The world is facing an energy crisis; oil prices continue to rise, and there are increasing concerns over Greenhouse Gas emissions and dwindling fossil fuel reserves. Whilst many sustainable energy technologies such as wind and solar power show promise, it seems unlikely that they will be able to meet all of the world’s ever-increasing demands. Although conventional nuclear fission reactors have the advantage of very low emissions, they create long half-life hazardous waste and provoke strong public concerns over their safety. For all these reasons scientists have been exploring an alternative nuclear technology, fusion. The basic principle of a fusion reactor is to heat a gas of hydrogen isotopes, deuterium and tritium, to many millions of degrees, causing them to fuse together into helium, and releasing vast amounts of energy in the process. Fusion is the process that powers the sun.

Fusion has several significant advantages over fission. The raw materials can be extracted from seawater, and the reaction product is helium, not a long-lived radioactive isotope. The reactor does not contain enough fuel at any given time for a catastrophic runaway reaction of the type that can occur in fission reactors. All of these factors coupled with its zero Greenhouse emissions, make fusion power a very attractive option for massive scale power generation.

The technical difficulty in achieving fusion is great but not insurmountable. Since work began in the 1950s prototype reactors have shown a steady increase in the ratio of power out to power in, and current experimental reactors are beginning to reach “breakeven point”. Within a decade or two, most scientists expect experimental reactors will be producing significant power.

Naturally, given the complexity of developing a working fusion reactor and the size and expense of such a project, most work in this area is carried out by many nations in partnership. Through the H-1 Heliac (left) and the MagPIE materials facility (right) of the Australian Plasma Fusion Facility based in Canberra, Australia is able to actively participate in this international effort.

MagPIE is a linear device for studying the interaction of plasma with materials, including materials suitable for fusion reactor walls. Although plasma temperatures are low, conditions are relevant to those in the divertor of a fusion reactor. The H-1 Heliac is a toroidal stellarator capable of holding super-heated plasma in a twisted magnetic loop. Albeit on a much smaller scale than prototype reactors such as ITER (below), H-1 offers excellent flexibility in its configuration and is particularly suited to the development of advanced diagnostic instrumentation. Some of this instrumentation has been employed on large scale reactors overseas and some has also been adapted to service other industries at home. In addition to its scientific value to Australia, the facility also offers an excellent training ground for young Australian scientists and engineers.

The development of the Facility was supported by an $8.7M establishment grant from the Department of Industry Science and Resources (1997-2010) and EIF funding for a $7M upgrade (2010-2013). The facility is operated by the Australian National University and is available through the Australian Institute of Nuclear Science and Engineering (AINSE) to researchers from around the country and internationally through collaborations.

Front Cover – New gas-cooled radiofrequency antenna used to form and heat H-1 plasma, toroidal magnetic field coils in the background, helical conductor in the lower foreground. Design, installation and photos by John Wach.
# EXECUTIVE SUMMARY

## I. EDUCATIONAL INFRASTRUCTURE FUND UPGRADE ANNUAL REPORT

### I.1 Facility Mission and Outcomes

### I.2 The Education Infrastructure Fund (EIF) Facility Upgrade

#### I.2.1 Scope of the Upgrade

### I.3 Status of the Upgrade Project – Progress in 2012-13

### I.4 Upgrade Highlights

#### I.4.1 The 21 Channel Imaging Plasma Density Interferometer

#### I.4.2 High Resolution Spectroscopic Imaging System

#### I.4.3 Commissioning the Materials Interaction Device MAGPIE in its Final Form

### I.5 Financial and Performance Summary

#### I.5.1 Milestone Progress and Project Performance Indicators

## II. FACILITY PROMOTION

### II.1 Publications

### II.2 Invited Talks

### II.3 Service to Outside Organisations

### II.4 Outreach Activities

#### II.4.1 Teaching

### II.5 Visitors

## III. COLLABORATION, EDUCATION AND TRAINING

### III.1 Collaborative Ventures

### III.2 Higher Degree Research Completions

## IV. STAFFING AND ADMINISTRATION

### IV.1 Management Structure of the H-1 National Facility

### IV.2 Board Membership

### IV.3 ANU Facility Staff

## V. GRANTS AWARDED

## VI. PROJECT PROGRESS VERSUS MILESTONES

## VII. FINANCIAL STATEMENTS

---

*The Australian Plasma Fusion Research Facility, operated by the Plasma Research Laboratory, Research School of Physics and Engineering in the College of Physical and Mathematical Sciences, The Australian National University, Canberra, Australia. [http://apffrf.anu.edu.au](http://apffrf.anu.edu.au)*

*This report covers July 2012 to June 2013 except for some papers from earlier in 2012 which were omitted from the previous report.*
Research Highlights

The new RF system has enabled the first scans of the dependence of the frequency instabilities on magnetic field strength. Initial results show Alfvénic scaling under some conditions, consistent with the observed density dependence.

Good agreement has been obtained between measurements of wave propagation in the MAGPIE materials device and a numerical helicon wave model. Understanding how plasma is produced by these waves will inform the design of the larger successor.

A new type of Langmuir probe, known as a Ball Pen probe, has been installed on a stellarator for the first time. Initial results indicate that the probe can measure the plasma potential directly under suitable circumstances. Normally this must be obtained indirectly from several separate measurements.

Artificial (CVD) diamond samples were exposed to plasma in MAGPIE. Analysis by ANSTO scientists at the Australian Synchrotron including Near Edge X-ray Absorption Fine Structure (NEXAFS) Spectroscopy shows that damage to the surface of the diamond films is restricted to the depth of penetration of hydrogen ions.

Upgrade Highlights

A new High Resolution Spectroscopic Imaging System has been brought into full operation on H-1 to image intensity ratios of helium and hydrogen/deuterium spectral lines to determine plasma density and electron temperature.

A plasma glow discharge system to actively clean internal surfaces of the vacuum vessel and structure, reducing impurity contamination, especially from carbon and oxygen, has been designed, manufactured and installed on the H-1 facility. This should allow access to higher temperatures.

The prototype MAGnetised Plasma Interaction Experiment (MAGPIE) has been commissioned in its final state including the new shielded and electrically insulated target holder. This was designed and constructed at ANSTO, and has already enabled a greater variety of target materials to be tested, including tungsten, its alloys, and artificial diamond, at various ion energies.
Executive Summary

The upgrade of the Australian Plasma Fusion Research Facility under the Super Science Initiative Scheme is almost complete. The expected outcomes of this financial support are:

- Significant improvements to the plasma formation and heating systems, vacuum systems and plasma diagnostic and data systems.
- Enhanced accessibility of plasma data and diagnostic information.
- Dual use of heating, magnet supply and diagnostic systems with a new high power and high plasma density Materials Diagnostic Development Facility prototype (MAGPIE).
- The development of diagnostic tools, which it is hoped, will ultimately be installed on the international fusion experiment ITER. This is identified as a central plank of the “Strategy for Australian Fusion Science and Engineering” developed by the Australian ITER Forum in consultation with the Australian fusion community.

As a result of funding uncertainty, loss of a key staff member and other factors, agreement was reached to extend the time frame of the upgrade by six months. All of the adjusted milestones were met, including:

- ‘MAGPIE’, the prototype MAGnetised Plasma Interaction Experiment, was upgraded to its final form, including a new target holder.
- The final acceptance tests of the new radiofrequency plasma heating sources were successful including some site-specific modifications.
- The seven channel prototype electron density interferometer was upgraded to the full 21 channels, to provide profiles of density across the entire cross-section.
- A third magnetic field control parameter has been fully integrated into the control system increasing the range of configurations available to H-1.
- A glow discharge cleaning system has been installed to complement the pulsed discharge cleaning, to improve the vacuum quality of H-1.
- The high resolution imaging spectrometer system for measuring electron density and temperature profiles was enhanced by additional baffling and integrated into the data system.

Operational funding issues for FY 2013/14 and FY2014/15 have been resolved, initially by a promise of bridging support from the University, and ultimately by the allocation of funds in the 2013/14 budget for the operation of NCRIS Facilities over that period. While this allows us to retain operational and maintenance staff, as the upgrade approaches completion, we will regrettably lose the valuable services of three contract staff, who have done an excellent job.

The following document is the EIF Upgrade Annual Report 4 including research and other outputs. More detailed information on the Facility and research results will be contained in the EIF Final Report of the Infrastructure Upgrade, to appear shortly.
I. Educational Infrastructure Fund Upgrade Annual Report

1. Facility Mission and Outcomes

The Facility, built around the H-1 heliac and the MAGPIE materials interaction device is the Australian focus of basic experimental research on magnetically confined plasma, important in developing fusion energy – a clean, virtually inexhaustible energy source that powers the sun and stars.

The mission of the Facility is to:

- perform research into the basic properties of magnetically-confined, high-temperature plasma as part of an international program, whose ultimate aim is ecologically sustainable power generation by the controlled fusion of hydrogen isotopes
- ensure that Australia is intellectually and technologically equipped to benefit from a future fusion power industry, with emphasis on the export of high-technology components needed by fusion power stations
- maintain Australia’s internationally recognised position of excellence in basic plasma physics and applications such as plasma diagnostics and plasma materials interaction.

The anticipated research outcomes of the Facility include:

- a detailed understanding of the behaviour of hot plasma which is magnetically confined in the helical axis stellarator configuration – this forms part of an international program under the International Energy Agency (IEA) Implementation Agreement on Stellarators, to which Australia is a party
- the development of advanced plasma measurement systems (‘diagnostics’), integrating real-time processing and multi-dimensional visualisation of data
- fundamental studies of turbulence and transport of particles and energy in confined plasmas
- significant contributions to the global fusion research effort and an increased Australian presence in the field of plasma fusion power into the 21st century
- improvements in knowledge of basic plasma physics
- better understanding of the interaction between plasma and materials, especially under the extreme conditions expected in fusion reactors.

An important performance indicator was identified as ‘technological spin-off activities’ in areas including instrumentation and techniques. More detail on the Facility and its existing infrastructure and power and instrumentation systems follows. Outputs are summarized at the end of the section, and described in more detail Sections II and III.
I.2 The Education Infrastructure Fund (EIF) Facility Upgrade

In its 2009-10 Budget the Australian Government announced a $1.1 billion Super Science Initiative to build on the National Collaborative Research Infrastructure Strategy (NCRIS) investments in research infrastructure. As part of this initiative, $7 million was allocated to the upgrade of Australia’s plasma fusion research capabilities, the need for which was identified in the 2008 Strategic Roadmap for Australian Research Infrastructure.

The Australian Plasma Fusion Research Facility (APFRF, formerly the National Plasma Fusion Research Facility) is a uniquely versatile plasma research facility, located in the Research School of Physics and Engineering within the College of Physical and Mathematical Sciences of the Australian National University in Canberra. It is capable of accessing a wide range of plasma configurations or shapes, and utilising associated state-of-the-art power and measurement systems that allow fundamental studies of plasma, the fourth state of matter. The facility is operated by the staff from the Plasma Research Laboratory, and serves both national and international collaborators including researchers from China, Japan, Korea, Germany, and the United States.

A core component of the Facility is the H-1 Heliac plasma confinement device (Heliac). The Heliac allows investigation of basic plasma physics and exploration of ideas for improved magnetic design of the fusion power stations that will follow the ITER international fusion experiment in France. While the Heliac’s shape prevents its use in a reactor, its high degree of flexibility allows testing basic plasma theory over a wide range of conditions, making it ideal for a university or research environment. Similarly, the Facility provides a convenient, flexible and well diagnosed test-bed for development of plasma measurement systems for both stellarators and tokamaks, an area where Australia is at the international forefront.

In 2011, funded by the EIF Infrastructure Upgrade, a facility for studying the interactions between plasma and materials was established, taking advantage of existing Facility infrastructure and diagnostic systems. The prototype device MAGPIE (MAGnetised Plasma Interaction Experiment) provides plasma conditions approaching those at the edge of fusion reactor, and opens up the Facility to a growing community of Australian materials researchers. It is becoming increasingly recognised that one of the main challenges of fusion power is finding materials able to withstand the extreme conditions expected in fusion reactors.

The objectives of the upgrade are to:

- upgrade the technical capabilities of the APFRF by replacing or upgrading various components of the Heliac system such as the plasma generation and heating system and associated antennas, the vacuum system, the plasma measurement systems, precision current regulator, and fast cameras
- boost Australian capability in fusion science and engineering by making the facility more accessible to national and international researchers
• offer open access to data arising from the Facility upgrades to relevant research communities
• offer merit-based access to the research infrastructure upgraded and built through the Project

In the 2008 Strategic Roadmap for Australian Research Infrastructure, fusion was included under the Sustainable Energy Future capability among long timescale candidates as a potential large-scale, non-polluting energy source. The Roadmap identified that plasma fusion required concerted international collaboration, investment in local capabilities including experimental facilities, and co-operation to bring to commercial reality. The upgrade of the APFRF is part of this investment.

In addition to increased technical capabilities, the upgrade will develop capabilities and expertise by fostering student, postgraduate and post-doctoral training. It will also facilitate the development of measurement systems suitable for application to current and next generation fusion power experiments such as the ITER experimental fusion reactor.

I.2.1 Scope of the Upgrade
Following is an outline of the scope of those elements of the upgrade which were active this year. The next section reports on the status of those projects.

Upgrade of the RF heating system, cooled antenna and matching network: The RF system used to generate plasma in the H-1 has proven to be the most often-used method of plasma formation and heating, because of its flexibility of frequency, modulation and the phasing of elements in the antenna. The upgrade will more than double the available power, improve reliability and facility uptime, and reduce electric power costs. The ability to vary frequency, power and relative phase of the antenna elements over a wide range under computer control considerably enhances the flexibility of the Facility.

Vacuum upgrades: Vacuum quality will be improved by the combination of glow discharge cleaning to remote surfaces inside H-1, with pulsed plasma cleaning of surfaces close to the plasma. These are enabled by new glow discharge cleaning electrodes and by the new cooled antenna respectively and are effective in removing oxygen and carbon impurities from the chamber walls and internal structures. These upgrades will allow better impurity control, which is necessary for achieving higher ionisation states, and for dealing with material ablated or sputtered from wall material tests.

Dual use of power, heating and diagnostic systems on the Materials Diagnostic Facility: Taking advantage of facility power systems and diagnostic infrastructure, the small MAGPIE device (described later in §I.4: Upgrade Highlights) will allow tests of plasma edge and plasma-wall interaction diagnostics under conditions approaching the edge plasma in a fusion reactor. This provides much higher power density and plasma density conditions than in H-1.

Installation of a precision current regulator: This will allow better and more controlled access to island divertor plasma configurations.
Upgrade of the data system and databases: The upgrade will make data more readily available, especially to users not intimately familiar with details of H-1 operation. In conjunction with this, a greater degree of automation of measurement systems (diagnostics) will ensure that key diagnostics are available on all shots. This year, focus is on a database of magnetic configurations including finite pressure effects.

Upgrade of the High Voltage Electrical Bay: This includes removing or replacing some aging transformers, and bringing the installation up to the required standards.
I.3 Status of the Upgrade Project – Progress in 2012-13

Following is a brief summary of the status and progress made on the Facility upgrade the year, grouping associated milestones together. Some of the topics are treated in more detail in Upgrade Highlights, and the complete list of Milestones for the project is provided in Section VI.

This year’s upgrade saw the essential completion and integrated operation of several key plasma diagnostic systems. The density interferometer has now been upgraded to 21 channels and provides a complete coverage of the plasma cross-section. The overall performance is much improved due to expanded optical components such as large Fresnel lenses and extended wire polarizers, a novel anti-reflection coating of lenses and windows to avoid multi-path reflections (section I.4.1), as well as an automated phase and object imaging test jig for system evaluation and calibration. A new High Resolution Spectroscopic Imaging System has been installed and operated to image intensity ratios of helium and hydrogen/deuterium spectral lines to determine plasma density and electron temperature. It consists of a high resolution imaging spectrometer and a fast image-intensified camera, coupled to H-1 via a shrouded ‘periscope’ optical imaging transmission system – see section I.4.2.

To provide a direct optical view of the plasma in the vicinity of the plasma-heating antenna inside H-1, a new re-entrant port was manufactured and installed. The simultaneous operation of a newly installed supersonic gas injector at this location offers scientists new opportunities to study plasma radio frequency heating mechanisms.

Vacuum upgrades:

A plasma glow discharge system to actively clean internal surfaces of the vacuum vessel and structure, reducing impurity contamination, especially from carbon and oxygen, has been designed, manufactured and installed on the H-1 facility. It includes three installed discharge electrodes and two remote operated high-voltage power supplies, capable of simultaneously operating all three electrodes. A new Residual Gas Analyser head was installed on a specially designed side arm to extend the range of monitoring to the higher pressures used for glow discharge cleaning. Further vacuum improvements can be achieved with the installation of an efficient vacuum turbo-pump at the residual gas analyser on H-1. A comprehensive pump manufacturer market survey has been conducted and a supplier has been selected. This year’s upgrade included the commissioning of the new cooling cryogenic cooling coil to minimize residual water vapour inside experimental facility. These upgrades will allow better impurity control by combining glow discharge cleaning of remote surfaces inside H-1, with pulsed plasma cleaning of surfaces close to the plasma.
Upgrades of the MAGPIE prototype Materials Diagnostic Facility:

The prototype MAGnetised Plasma Interaction Experiment (MAGPIE) has been commissioned in its final state and is routinely operated. The device makes dual use of H-1 plasma diagnostic systems to study plasma conditions closer to those expected at the first wall of a fusion reactor. Upgrades include the commissioning of the new shielded and electrically insulated target holder, and successful use for some materials and diagnostics experiments. The device routinely produces plasma with up to 3kW of RF at 13.56 MHz in argon plasma and up to 20 kW with hydrogen to achieve high plasma densities (~10^{19} \text{ m}^{-3}) in the magnetic pinch region of the chamber. More details are provided section I.4.3.

A technical feasibility study has been completed for dual use of the plasma heating power systems to be shared between the H-1 facility and MAGPIE. Implementation work on this minor upgrade of existing systems will commence in 2014. This will provide higher power over a wide range of frequencies, and sustained operation at lower powers, initially 2kW. Increased power will accelerate materials interaction tests and allow greater throughput of test samples. The flexibility in power and frequency will allow scaling studies of plasma production to be made to inform the design of a larger, more powerful machine.

Upgrade of databases and data post processing tools:

The H-1 magnetic field data are now available in several standard formats (HDF5, NetCDF, VMEC) to provide compatibility with data post-processing tools of a wider user base. Optimization codes have been developed to provide researchers with tools to match experimental data with modelled magnetic field line codes.

Upgrades have been made on the H-1 data server and web interface to provide uniform access to APFRF data and data from some International Facilities. This also affords improved online data viewer capabilities, a wider spectrum of available summary meta-data and an automated data backup system.

Upgrade of general facility infrastructure:

The emergency interlock system has been revised with the addition of emergency stop buttons in the plant room of the plasma heating equipment. All backup power supplies have been replaced to ensure uninterrupted operation for all computer and control systems of the H-1 facility in case of a power failure. The industrial control system (PLC) has been upgraded to the latest version for reliability and improved performance. The computational infrastructure has seen an essential upgrade in a doubling of the data-backup storage capacity to almost 11TB. Data access and storage was substantially improved by this year’s network cable upgrade around the H1 experimental facility. 24 new Ethernet ports were installed to provide high-speed transfer rates for plasma diagnostic, data acquisition and operational control systems.
I.4 Upgrade Highlights

The following is a more detailed technical description of a selection of equipment and diagnostic projects enabled by the EIF upgrade funding in 2012-13.

I.4.1 The 21 Channel Imaging Plasma Density Interferometer

The plasma density is of fundamental importance, and is obtained by measurement of the density of free electrons using a microwave interferometer. In H-1NF the profile of density across the plasma is obtained by a multi-channel imaging technique to obtain maximum spatial resolution. The Phase I 7 channel prototype employed microwave imaging techniques to reduce the effects of diffraction on the resolution of the interferometer. This year, Phase II of the upgrade involved replacement of all the optics, the design of which was proven in the prototype Phase I implementation. The new optical elements were expanded in size to obtain complete coverage of the plasma cross-section, and used special surface machining to reduce reflections. Signal quality was improved by carefully controlling the polarisation of the millimetre wave beams. Both the polarisation and antireflection used high precision numerically controlled machining to create intricate patterns on the TPX lenses and plates, described in more detail below.

The lenses required were so large (600mm) that they were made using the Fresnel design on one side to reduce weight. Extensive simulations were performed using the ‘meep’ Finite Difference Time Domain electromagnetic optics simulation package. On the other (planar) side, a pyramidal array was precision machined to simulate a gradient in refractive index which reduces reflections.

The polarisation technique required a ‘quarter wave plate’, a birefringent component which in combination with a linear polarising grid, converts a plane polarised beam into circular polarisation to prevent feedback of radiation into the microwave source, and to improve

\[ \text{Figure 1: View of interferometer showing Fresnel lenses and detectors} \]
efficiency. This was implemented by cutting a precise two dimensional array of over a thousand sub-millimetre grooves into thin TPX sheets.

Figure 2 shows initial measurements of hydrogen plasma at three different times. Although one detector channel is not working in this example, due to ‘infant mortality’ of one of the sub miniature zero-bias detector diodes, graph shows that analysis software can cope with this. It can be seen that the density is close to zero at the extremes of the array, confirming that the coverage of the plasma is complete. The commissioning tests have suggested further improvements, which will be implemented in 2014.

![Figure 2: Initial data from the 21 channel interferometer - Time variation of electron density displayed as a false colour image, and a graph of electron density across the plasma at the three times indicated on the image](image)

I.4.2 High Resolution Spectroscopic Imaging System

The High Resolution Spectroscopic Imaging System high consists of a high resolution imaging spectrometer and fast image-intensified camera, coupled to H-1 via a shrouded ‘periscope’ optical imaging transmission system. The main purpose of this instrument is to capture images of line ratios of helium and hydrogen/deuterium spectral lines. This enables determination of complete profiles of plasma density and electron temperature in the first instance, and the differences in behaviour of hydrogen and its isotope deuterium in the second.

This application will centre on a collisional radiative model developed by Goto, et al. 2003, embedded in a model to perform statistical inference of the profiles. This code will also perform the necessary tomography for inference of both electron temperature and density profiles across the entire the plasma. New capabilities include local temperature and density profile measurement in combination with the Sydney University supersonic helium beam.
I.4.3 Commissioning the Materials Interaction Device MAGPIE in its Final Form

The extreme temperatures and heat and neutron flux produced by fusion reactors puts unprecedented demands on the materials close to the plasma, such as the “first wall” and “divertor targets”. Research into suitable “extreme materials” is of the highest priority, and is being conducted in several Australian Universities and at ANSTO. A small linear plasma device was constructed to augment the Facility with an environment to measure and understand the interaction of these materials with plasma, at high heat fluxes.

The MAGnetised Plasma Interaction Experiment (MAGPIE) is the first generation plasma-materials interaction and diagnostic development device within the Australian Plasma Fusion Facility. The device is smaller and simpler than H-1, has better access, and makes dual use of H-1 power heating and diagnostic systems to produce plasma conditions closer to those expected at the first wall of a fusion reactor. This enables investigation into plasma-material interactions, and the development and testing of new diagnostic techniques to provide additional data and further understanding.

With the commissioning of the new shielded and electrically insulated target holder (below), and successful use in some materials and diagnostics experiments, the first generation satellite device “MAGPIE” is now in its final form. The device routinely produces plasma with up to 3kW of RF at 13.56 MHz in argon plasma and up to 20 kW with hydrogen to achieve high plasma densities ($\sim 10^{19}$ m$^{-3}$) in the magnetic pinch region of the chamber [lower right, Figure 3]. Typical electron temperatures are $\sim$ 3-5 eV, (35,000-60,000 C).
A multi-channel photomultiplier diagnostic was installed on MAGPIE to allow spatial resolution of spectral lines in the optical range, and a high resolution spectrometer has been ordered, funded ($85,000) by the ANU Major Equipment Grant Scheme.

Collaboration between the ANU and the Australian Nuclear Science and Technology Organisation (ANSTO) brings together key capabilities – innovations in the design, manufacture and characterisation of advanced materials, and the basic science of the interaction of plasma with such materials, as described below.

**The Upgraded Target Holder**

An example of this collaboration provided a significant highlight in 2012 - the addition of a second-generation target holder to the MAGPIE facility. The new target holder was designed

---

*Figure 4: Ion Density of $10^{19}$ m$^{-3}$ was achieved in MAGPIE in hydrogen with 20kW of RF power. The generation efficiency jumps by a factor of 3-5x around 4kW. (The inset shows earlier results, demonstrating the increase in density resulting from the increasing field in the target region. Argon, being more easily ionised provides an even higher density).*

*Figure 5 Photo of the target holder illuminated by a low density helium MAGPIE plasma.*

The 10mm square sample under test can just be made out in the centre of the circular plasma facing surface. The outer shield, removed in the plasma photo, is shown in the inset, which also gives a better view of the 10mm square sample.*
and developed at ANSTO, and was first exposed to the MAGPIE plasma in October 2012 [Figure 5]. The design enables various fusion-relevant materials to be introduced into the target region. The target holder can be biased at various potentials to change the incident ion energy. A shield, grounded to the chamber was added in January to enable measurement of the ion flux at the target, and to reduce generation of impurities. ANSTO and ANU researchers successfully treated a number of material samples with the holder early in 2013.

Initial results of work performed in collaboration with Daniel Riley and members of the Extreme Materials for Fusion project at ANSTO are shown in Figure 5, in which pure tungsten and tungsten-alloy were bombarded by a helium plasma. Samples were exposed to a total dose of $10^{19}$ ions cm$^{-2}$ at a flux rate of $10^{17}$ ions cm$^{-2}$ s$^{-1}$, with ion energies up to 250 eV. It can be clearly seen that the pure tungsten sample has only been affected slightly by the plasma while that of the tungsten-alloy displays blistering on the surface possibly due to the accumulation of helium under the surface. Interestingly, no such effect was observed when the material was bombarded with hydrogen or argon plasma.

This device will provide a diagnostic test-bed capable of much higher repetition rates, and a much faster vacuum opening/closing cycle for installation of different diagnostics, probes and material targets. It will also be more practical to clean the device if contaminated with carbon or metal deposits, compared to H-1, so it will allow a wider range of materials to be tested, under higher power conditions, without fear of contaminating H-1.

Figure 6: Recent results from the ANSTO-ANU collaboration on the MAGPIE device of the Materials Diagnostic Facility: samples of helium plasma-irradiated pure tungsten (left) and of irradiated tungsten-alloy (right), showing blistering on a scale of microns.
Integration of the Precision High Current Controller: Access to New Plasma Configurations

A key feature of H-1 enabling fundamental plasma physics studies is the flexibility in plasma configuration. This is achieved most notably by controlling the current in the helical winding, which changes the twist (rotational transform) of the plasma, and can be used to avoid or access resonant configurations, with their associated magnetic islands. As this and the overall magnetic field strength are the two most important control parameters, the two high current precision power supplies are usually configured to control these. The other three winding sets, the ring conductor, and the inner and outer vertical field windings could only be operated with very limited control if any.

The precision high current controller, by dividing the applied current electronically, provides a third computer-controlled parameter and thereby enables access to a much wider range of magnetic configurations for plasma confinement studies. The custom designed, high-power electronics shunt, was prototyped as the main theme of two Honours projects, and constructed in the Research School of Physics and Engineering.

A remote real-time computer controls the selection of coarse adjustments using large circuit breakers, and steers the high speed pulse width modulation controller, at the direction of the main H-1 programmable logic controller (PLC). This has been integrated into the distributed H-1 control system, logging automatically to the MDSplus database, and allowing three parameter computer-controlled scans of configurations.

The extended range of plasma configurations and shapes now accessible to the H-1 Heliac is a continuous range of configurations between those previously accessible. In particular this allows a much finer control near the N=6, M=5 island, a naturally occurring island in H-1 which is representative of islands found in fusion relevant devices.

1 Previously control had been limited to: Outer vertical: factors of 0, 0.5, 1.0 and 1.5, Inner vertical: factors of -1, 0, +1, and ring conductor – no useful option other than a factor of +1. -
I.5 Financial and Performance Summary

The financial statement in Section VII shows that at June 30th 2013, of the total of all instalments from EIF funds of $7M, the EIF project balance was $341,368. This is projected to be adequate to complete the upgrade project.

The ANU (draft) in kind contributions below reflect reduced emphasis on operations and increased emphasis on project management during the upgrade. The overheads were calculated using a procedure described in the AVCC 1996 model, using an ‘ARC’ multiplier of 1.25 for academic and professional staff. The total is a little higher than anticipated due to the use of a different overhead model. The ANU contributions in kind were:

<table>
<thead>
<tr>
<th>The Australian National University – Direct Facility Support FY2012/13</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Director, Head Diagnostics, Operations Manager (Pro rata salary including Overheads according to ARC Multipliers, ARC overhead only for professional staff)</td>
<td>$552,069</td>
</tr>
<tr>
<td>• Other Support Staff (Pro rata salary)</td>
<td>$39,823</td>
</tr>
<tr>
<td>• Operation and Maintenance costs</td>
<td>$78,522</td>
</tr>
<tr>
<td>• Lab space occupied by Facility and Subsystems</td>
<td>$218,390</td>
</tr>
<tr>
<td>Total ANU in kind contribution to direct facility support (draft)</td>
<td>$888,804</td>
</tr>
</tbody>
</table>

Table 1: ANU in-kind contributions

The 2013-2014 Federal Budget made provision for ~$180M funding for operation and maintenance of National Facilities, for the period July 2013 to June 2015. The APFRF was allocated $900,000 for the two year period, allowing operations to continue at full capacity.
I.5.1 Milestone Progress and Project Performance Indicators

The table in Section VI lists the project Milestones, completed and pending. The Facility Upgrade Project Performance Indicators are reported against below, as required under the terms of the EIF funding agreement. Some of the indicators reflect the impact of the upgrade process on research and utilisation. For example, the RF power system final commissioning prevented operation for two weeks in December, and the vacuum upgrade for 4 weeks in October.

Providing Research Infrastructure

Value of all infrastructure made available under EIF
- cost and description of major items (value of aggregated systems to be supplied from insurance documents when updated)
  Insurance value is $32.5M

Performance against EIF principles

Principle 1: National research and infrastructure priorities addressed
The Australian Plasma Fusion Research Facility addresses two research priorities
“An Environmentally Sustainable Australia”, and
“Frontier Technologies for Building & Transforming Australian Industries
Priorities more specific than the National Research Priorities are yet to be defined in the current Roadmap process, but in relation to infrastructure priorities, the APFRF addresses the priority capability of the NCRIS 2006/2008 roadmaps
“A Sustainable Energy Future”

Principle 2: Significant benefits and effective use of resources, including new capabilities provided by the infrastructure upgrade.
New capabilities provided this year are:
  i. New shielded, isolated target holder for the MAGPIE materials facility in its final form, allowing acceleration of tests by increasing particle flux, and reducing unintended sputtering of extraneous materials.
  ii. Fully integrated access to new plasma configurations in H-1 using the precision current controller
  iii. A high speed (50kHz), high resolution 21 channel profile measurement of electron density
  iv. Further improvements and extension of user-friendly data access to some data from international facilities, and extension of the magnetic configuration database to include HDF, NetCDF and VMEC files.
  v. A high resolution, high speed imaging spectrometer allows time, space and wavelength-resolved optical emission profiles across the entire plasma cross-section. New capabilities include local temperature and density profile measurement in combination with the Sydney University He beam.

Principle 3: Infrastructure needs addressed
The facility provides the only high temperature plasma in Australia, and the only stellarator device in the Southern Hemisphere.
The Materials Diagnostic Facility also provides Australia with a unique capability for testing high temperature materials in an extreme environment, complementing facilities at ANSTO and elsewhere.
**Principle 4: Achievement of established standards in implementation and management**

Project management techniques are based on best practice in the context of the research environment. For each upgrade project, technical requirements are specified in consultation with Facility users. This is complemented during implementation by regular project-specific meetings to achieve the desired outcomes.

**Meeting Researcher Needs**

- **Number, type and affiliation of users of and visitors to the Facility**
  Users of Facility, Instrumentation and/or Data:
  The APFRF has approximately 40 current users of the facility, facility instrumentation and/or data. More than half of these are based in Australia. There are an additional approximately 10 currently inactive users, many of whom are likely to resume activity in the future.
  Research related International visitors:
  10 (see Annual report section IV.6)

- **Availability and usage of the Facility.**
  The H-1 Facility was available for all but 12 weeks in FY 2012-13. Downtime included two weeks for the RF power system final commissioning, four weeks for the vacuum upgrade in October/early November, and six weeks around the beginning of the year including annual leave, maintenance, cryopump upgrade and testing, a time of very low demand due to ARC proposal preparation.
  The MDF Facility prototype has been in operation in the newly fitted out laboratory for almost all of the available 5 days/week except for four weeks over Christmas, and two weeks due to a vacuum window problem. Hydrogen, Deuterium, Helium and Argon gases are regularly available.

**Quality of Research Infrastructure**

- **Specific comparisons against comparable facilities or instruments, in Australia and overseas**
  The Facility is unique in Australia (and in the Southern Hemisphere/South East Asia) – the only directly comparable facility is TJ-II in Spain. H-1 has better diagnostic access, and more precise configuration control; TJ-II with a much larger budget, has several different plasma heating systems, higher heating power, and plasma closer to fusion conditions.

- **International recognition, as evidenced by consulting or uptake of instrumental and diagnostic infrastructure technologies developed on this Facility**
  Advanced imaging: uptake onto DIII-D (USA), Textor (EURATOM), KSTAR (Korea), Max Planck IPP Greifswald (Germany)
  Data mining: MHD fluctuations: uptake National Institute for Fusion Science/Kyoto Univ (Japan), TJII/CIEMAT (Spain), Max Planck IPP, Greifswald (Germany)

**Collaborative Infrastructure Provision**

- **Types, extent and duration of collaborative agreements/relationships established for developing or exploiting research infrastructure**
  - IEA Implementing Agreement (since 1985, renewed 2010, 7 countries + EC)
  - MOU of collaboration with the National Fusion Research Institute, Korea
  - Collaborative agreement for comparative study of Heliac and Heliotron devices, Kyoto University, 2005—
• Long standing collaborative agreements with Princeton Plasma Physics Laboratory and the National Institute of Fusion Science have allowed exchange of equipment, sabbatical exchanges, and access to facilities.
  o Access to machine time on international facilities enabled by the Facility and the research it supports
    2012-2013: Facility access to KSTAR, Korea:
      John Howard – Motional Stark Effect Imaging: 1 day dedicated operation
      Matthew Hole – MHD instability studies: one half day dedicated operation.

Fostering Collaborative and World-class Research
  o Number and nature of Australian and international research collaborations that involve use of the Facility
    Comparative Study of H-1 and Heliotron-J - Kyoto University
    An International MHD Data mining project - Kyoto University, CIEMAT, Spain, IPP, Germany, National Institute of Fusion Science, Japan.
    Observations of plasma effects in detonations - DSTO
    MHD Instabilities in toroidal devices - Princeton University, Oak Ridge National Laboratory
    Material Diagnostics under Fusion Plasma Edge Conditions - Materials Institute, ANSTO
    Three dimensional wave physics - Max Planck Inst. for Plasma Physics, Germany
    Burning Plasmas: resolving energetic particle physics for ITER - Culham Centre for Fusion Energy
    Emergence and control of self-organisation in fusion plasmas: through ITER and beyond - Univ. of Warwick, Princeton Plasma Physics Laboratory, Univ. of Padua.
    Analysis of KSTAR Alfvén wave fluctuations - National Fusion Research Institute, Korea.
    Bayesian Analysis of MAST and H-1 data: Culham Centre for Fusion Energy - Max Planck Institute for Plasma Physics, Germany
    Motional Stark Effect Imaging - Max Planck Institute for Plasma Physics, Germany
    Optical imaging systems for thermography and slag/iron discrimination at a molten iron furnace - BlueScope Steel Limited, Port Kembla
    Coherence imaging studies of KSTAR tokamak - Korean National Fusion Research Center
    Development of Diagnostic Imaging Systems for the Sydney University High Current Pulsed Arc - University of Sydney
    See §III.1: for details
  o Conferences and Workshops organised or attended, and International Invited papers and publications
    Chaired the International Program Committee 19th International Stellarator/Heliotron Workshop & 16th Reverse Field Pinch Workshop in September 2013

Refereed Publications in International Journals
  Design and characterization of the Magnetized Plasma Interaction Experiment (MAGPIE): A new source for plasma-material interaction studies
  At the Edge Plasma-Surface Science for Future Fusion Reactors
  Discharge kinetics of inductively coupled oxygen plasmas: experiment and model
  Computation of multi-region relaxed magnetohydrodynamic equilibria
Fast particle modifications to equilibria and resulting changes to Alfvén wave modes in tokamaks

Generalised action-angle coordinates defined on island chains

Hay fever in a changing climate: linking an Internet-based diary with environmental data

Helical bifurcation and tearing mode in a plasma—a description based on Casimir foliation

On the Regularity of Optimal Transportation Potentials on Round Spheres

Oscillon Dynamics and Rogue Wave Generation in Faraday Surface Ripples

Wave modelling in a cylindrical non-uniform helicon discharge

XMDS2: Fast, scalable simulation of coupled stochastic partial differential equations

A high spatial resolution Stokes polarimeter for motional Stark effect imaging

A unified method for inference of Tokamak equilibria and validation of force-balance models based on Bayesian analysis

First evidence of Alfvén wave activity in KSTAR plasmas

Gap eigenmode of radially localized helicon waves in a periodic structure

Inverse energy cascade and emergence of large coherent vortices in turbulence driven by Faraday waves

Plasma parameters and electron energy distribution functions in a magnetically focused plasma

The Infinite Interface Limit of Multiple-Region Relaxed MHD

NEXAFS spectroscopy of CVD diamond films exposed to fusion relevant hydrogen plasma

Lagrangian scale of particle dispersion in turbulence

Minimally Constrained Model of Self-Organized Helical States in Reversed-Field Pinches

Antenna Modeling and Reconstruction Accuracy of Time Domain-Based Image Reconstruction in Microwave Tomography

Using Bayesian analysis and Gaussian processes to infer electron temperature and density profiles on the Mega-Ampere Spherical Tokamak experiment

See § II for details, media presence, outreach publications, tours and other activities.
II. FACILITY PROMOTION

In 2012-13, outreach activities were carried out jointly with the Australian ITER Forum, in addition to promotional and awareness activities undertaken by Facility staff. These include the publishing of recent research results in a number of refereed journals (see Section II.1) and presentations by researchers at several national and international conferences (Section II.2). A number of collaborative ventures with national and international partners, government and private industry were also undertaken (see Section III.1). Visits to the Facility by national and international researchers and by prospective science students were organised, and service was provided by staff to a number of outside organizations.

II.1 Publications

Refereed Journal Articles

Boyd D Blackwell, Juan Francisco Caneses, Cameron M Samuell, John Wach, John Howard and Cormac Corr

*Design and characterization of the Magnetized Plasma Interaction Experiment (MAGPIE): A new source for plasma-material interaction studies*
Plasma Sources Science and Technology, Vol. 21, No.5, Page 1-7, 2012

Corr, C.

*At the Edge Plasma-Surface Science for Future Fusion Reactors*

C S Corr, S Gomez and W G Graham

*Discharge kinetics of inductively coupled oxygen plasmas: experiment and model*
Plasma Sources Science and Technology, Vol.21, No.5, Page 055024/1-13, 2012

S.R. Hudson, R.L. Dewar, G. Dennis, M.J. Hole, M. McGann, G. von Nessi, S. Lazerson

*Computation of multi-region relaxed magnetohydrodynamic equilibria*
Physics of Plasmas, Vol.19, No.11, Page 112502/1-18

M J Hole, G von Nessi, M Fitzgerald and the MAST team

*Fast particle modifications to equilibria and resulting changes to Alfvén wave modes in tokamaks*

Robert L. Dewar, Stuart R. Hudson, Ashley M. Gibson

*Generalised action-angle coordinates defined on island chains*
Plasma Physics and Controlled Fusion, Vol.55, No.1, Page 014004/1-10, 2012

Medek DE, Kljakovic M, Fox I, Pretty DG, Prebble M.

*Hay fever in a changing climate: linking an Internet-based diary with environmental data*
EcoHealth, Published online 27/10/2012

Z Yoshida and R L Dewar

*Helical bifurcation and tearing mode in a plasma—a description based on Casimir foliation*
Von Nessi, Gregory  
*On the Regularity of Optimal Transportation Potentials on Round Spheres*  
Acta Applicandae Mathematicae, Online July 2012

H. Xia, T. Maimbourg, H. Punzmann, and M. Shats  
*Oscillon Dynamics and Rogue Wave Generation in Faraday Surface Ripples*  

*Wave modelling in a cylindrical non-uniform helicon discharge*  

Graham R. Dennis, Joseph J. Hope, Mattias T. Johnsson  
*XMD2: Fast, scalable simulation of coupled stochastic partial differential equations*  
Computer Physics Communications, Vol. 184, Issue 1, Pages 201-208, 2012

Alex Thorman, Clive Michael and John Howard  
*A high spatial resolution Stokes polarimeter for motional Stark effect imaging*  

von Nessi Jr., G, Hole, M & MAST Team, T 2013  
*A unified method for inference of Tokamak equilibria and validation of force-balance models based on Bayesian analysis*  

Hole M, Ryu C, Woo M, Bak J, Sharapov S, Fitzgerald M, KSTAR Team T  
*First evidence of Alfvén wave activity in KSTAR plasmas*  

L Chang, B N Breizman and M J Hole  
*Gap eigenmode of radially localized helicon waves in a periodic structure*  

N. Francois, H. Xia, H. Punzmann, M. Shats  
*Inverse energy cascade and emergence of large coherent vortices in turbulence driven by Faraday waves*  

C M Samuell, B D Blackwell, J Howard, C S Corr  
*Plasma parameters and electron energy distribution functions in a magnetically focused plasma*  

G.R. Dennis, S.R. Hudson, R.L. Dewar, M.J. Hole  
*The Infinite Interface Limit of Multiple-Region Relaxed MHD*  
Physics of Plasmas, Vol. 20, No. 3, Pages 032509/1-6, 2013

Mathew C. Guenette, Alec Deslandes, Cameron M. Samuell, Anton Tadich, Lars Thomsen, Bruce C.C. Cowie, Cormac S. Corr, Daniel P. Riley  
*NEXAFS spectroscopy of CVD diamond films exposed to fusion relevant hydrogen plasma*
II.2 Invited Talks

**Corr, C.**

*The MAGnetised Plasma Interaction Experiment (MAGPIE): a new source for plasma-material interaction studies*

Invited colloquium at University of York (May 2012 – omitted from 2011-12 report)

*The MAGnetised Plasma Interaction Experiment (MAGPIE): a new source for plasma-material interaction studies*

Invited seminar at Ecole Polytechnique, Paris (May 2012 – omitted from 2011-12 report)

*Plasma fusion and the material challenge*


**Hole, M. J.**

*The potential for Australian participation in ITER*

Australian Institute of Physics Congress, Sydney December 2012

*Beam plasmas in fusion*


*Equilibrium model validation, and MHD models of anisotropy, flow and chaotic fields*

Invited Colloquium, Institute of Plasma Physics Garching, Germany, 10th July 2013

*Advanced MHD models of anisotropy, flow and chaotic fields*

12th Asia Pacific Physics Conference, 14-19 July 2013
Resolving the physics of anisotropy, flow and chaotic fields
Colloquium, Institute of Plasma Physics, Chinese Academy of Science, Hefei, China, 14th November 2012 (supported by Australia-China Young Exchange Program)

Resolving the physics of anisotropy, flow and chaotic fields
Colloquium, SouthWestern Institute for Physics, Chengdu 16th November 2012 (supported by Australia-China Young Exchange Program)

Resolving the physics of anisotropy, flow and chaotic fields
International Tokamak Physics Activity on Energetic Particles, 16 October 2012.

II.3 Service to Outside Organisations

B. Blackwell
Member, IUPAP Commission on Plasma Physics (C16)
Member, Executive Committee, IEA Implementing Agreement for Cooperation in Development of the Stellarator Concept

M. Hole
Member, Editorial Board, Plasma Physics and Controlled Fusion
Member, International Fusion Research Council, IAEA
Chair Australian ITER Forum
Program Committee, International Toki Conference 2013 “Large Scale Simulation and Fusion Science”
Judge, Eureka Awards for Innovative Use of Technology, 2012-2013 Expert Witness, Newcastle District Court, May 2013

J. Howard
Chair, 2014 Australian Institute of Physics Congress

II.4 Outreach Activities

M. Hole
ABC Radio Interview, 10 December 2012
The promise of fusion power, The Drum (ABC), 14 December 2012
http://www.abc.net.au/unleashed/4427806.html


C. Corr

Members' contributions to various submissions


Exposure Draft of the fusion Science Strategic plan 29/10/2012 “Powering ahead: A national response to the rise of the international fusion power program” Working Panel: Brian James (Convenor), Richard Garrett, Barry Green, Matthew Hole, John Howard and John O'Connor.

II.4.1 Teaching
M. Hole: taught Advanced Electrodynamics, Phys 4003F, 2013, ANU
M. Hole, Fusion contribution to Nuclear Science Masters course, 2009-2013, ANU
C. Corr: taught Plasma physics, 3rd year, 2011 and 2012, ANU
C. Corr: jointly taught 2nd year electromagnetism, 2012, ANU

II.5 Visitors
Dr Jay Larson, Argonne National Laboratory, USA
Dr Oday Jerew,
Mr John Wach
Dr Jana Brotankova, Institute for Plasma Research, India
Prof. Roger Hosking, University of Adelaide
Professor Lie Liu, National University of Defense Technology, Chengdu, China
Dr. Axel Koenies, Max Planck Institute for Plasma Physics (Greifswald), Germany
Dr Stuart Hudson, Princeton Plasma Physics Laboratory, USA
Dr. Daniel Riley, ANSTO
Dr. Mathew Guenette, ANSTO
Dr. Alex Deslandes, ANSTO
III. COLLABORATION, EDUCATION AND TRAINING

III.1 Collaborative Ventures

**B Blackwell**

**Project:** Comparative Study of H-1 and Heliotron-J  
**Partners:** Dr K Nagasaki, Dr S Yamamoto - Kyoto University

**Project:** An International MHD Data mining project  
**Partners:** Dr D Pretty - ANU, Dr S Yamamoto, Dr K Nagasaki - Kyoto University, Dr E Ascasibar - CIEMAT, Madrid, Dr A Werner – IPP, Greifswald, Dr S Sakakibara - National Institute of Fusion Science, Japan.

**Project:** Observations of plasma effects in detonations  
**Partners:** Dr J Waschl - DSTO

**B Blackwell, J Howard**

**Project:** MHD Instabilities in toroidal devices  
**Partners:** Dr R Nazikian - Princeton University, Dr J Harris - Oak Ridge National Laboratory

**C Corr, B Blackwell, J Howard**

**Project:** Material Diagnostics under Fusion Plasma Edge Conditions  
**Partners:** Dr D. Riley, Materials Institute, ANSTO

**C Corr**

**Projects:** Tuneable Diode Laser Absorption Spectroscopy on MAGPIE  
**Partner:** Dr Sean O’Byrne, ADFA

**M. J. Hole, R. L. Dewar, B. Blackwell**

**Project:** Three dimensional wave physics  
**Partner:** Dr Axel Koenies, Dr Caroline, Nuehrenberg - Max Planck Inst. for Plasma Physics

**M. J. Hole, Dewar R, M. Fitzgerald**

**Project:** Burning Plasmas: resolving energetic particle physics for ITER  
**Partners:** Dr Ken McClements, Dr Sergei Sharapov, Dr Simon Pinches, Culham Centre for Fusion Energy,

**Hole M, Dewar R, Blackwell B,**  
**Project:** Emergence and control of self-organisation in fusion plasmas: through ITER and beyond”  
**Partners:** Dendy R O., Univ. of Warwick / Culham centre for Fusion Energy, Hudson S R, Princeton Plasma Physics Laboratory, Escande D, Univ. of Padua.

**M. J. Hole**

**Project:** Analysis of KSTAR Alfven wave fluctuations  
**Partners:** Prof. C M. Ryu, Postech Univ., Korea, J. Kim, J.G. Bak, National Fusion Research Institute, Korea.
M. Hole, B. Blackwell, R.L. Dewar, J. Howard,
Project: Bayesian Analysis of MAST and H-1 data

J Howard
Project: Motional Stark Effect Imaging
Partners: Prof R. Wolf – ASDEX-Upgrade tokamak, Germany

Project: Divertor Doppler Imaging
Partner: Dr S. Allen – General Atomics, San Diego
Dr R. Sharples – MAST tokamak, UKAEA, England.

Project: Optical imaging systems for thermography and slag/iron discrimination at a molten iron furnace
Partner: Mr B Scott, Dr R Nightingale - BlueScope Steel Limited, Port Kembla

Project: Coherence imaging studies of KSTAR tokamak
Partner: Dr J Chung - Korean National Fusion Research Center

J Howard, M Shats, B Blackwell
Project: Development of Diagnostic Imaging Systems for the Sydney University High Current Pulsed Arc
Partners: Prof M Bilek, Dr R Tarrant and Prof D Mackenzie - University of Sydney

III.2 Higher Degree Research Completions

Ashley Gibson, M. Phil
Reconciliation of Almost-Invariant Tori in Chaotic Systems, 2012

Benjamin John Heslop, M. Phil
Collaborative Entrepreneurial Innovation, 2012
IV. STAFFING AND ADMINISTRATION

IV.1 Management Structure of the H-1 National Facility

The management structure involves four major organisations:

- The Department of Innovation, Industry, Science and Research (DIISR)
- The Australian Nuclear Science and Technology Organisation (ANSTO)
- The Australian Institute of Nuclear Science and Engineering (AINSE)
- The Australian National University (ANU)

all of which have input into the decisions made by the H-1NF Board.

At annual meetings, scientific and technical operational plans and associated budgets are developed, including Facility upgrades, collaborations, and research training plans.

At weekly meetings, the reduced Management Committee executes the operational plan and schedules experiments.

The role of AINSE lies mainly in the facilitation and coordination of Australian collaborations and the allocation of travel funds in support of this.

The Director oversees the implementation of the operation plan in accordance with the contract, including reporting to the Board.

The Board, and the Management Committees, have a direct impact on Facility policies.

Figure 8: H-1NF Management Structure

![Figure 8: H-1NF Management Structure]

Figure 9: Board members. BACK ROW: J Howard, B Blackwell, M Hole, J Söderbaum, H Punzmann, J Soria, M Shats, D Mather, R Dewar, R Storer. FRONT ROW: M Hewitt, H Rubinsztein-Dunlop, J O'Connor (Chair), J Baker, M Bilek. MISSING: Prof. S Buckman, A Paterson

26

The higher level role of the Australian Fusion Research Group has been subsumed by the larger entity presently known as the Australian ITER Forum, and at the lower levels, by incorporating active external researchers in the management committee.

The Management Committee consists of the Facility Director and Manager, leaders of Facility research pursuits, and representatives or nominees of users' organisations and proponent organisations, one per organisation. The structure provides a clear mechanism for proponent organisations and users to have effective input to Facility operations planning, and equitably allows for the Director to also be a Facility user. This Committee meets annually, in conjunction with a conference or workshop if convenient, with (as close as possible) full membership, and weekly, in a reduced form with the members that are on site or wish to join via teleconference.

As part of the upgrade process, an Annual Business Plan is developed. Scientific and technical operational plans and associated budgets are developed, including Facility upgrades, collaborations, and research training plans, consistent with the Facility Business Plan and this Project Plan. If a vote is required, sufficient members will abstain from voting so that an equal number of ANU and non-ANU representatives cast votes. At weekly meetings, the reduced Management Committee executes the operational plan and schedules experiments.

**IV.2 Board Membership**

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution/Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor John O'Connor (Chair)</td>
<td>University of Newcastle</td>
</tr>
<tr>
<td>Dr Boyd Blackwell</td>
<td>Director, APFRF</td>
</tr>
<tr>
<td>Dr Horst Punzmann</td>
<td>Facility Manager, APFRF</td>
</tr>
<tr>
<td>Dr Adi Paterson,</td>
<td>ANSTO</td>
</tr>
<tr>
<td>Emeritus Professor Robin Storer</td>
<td>Flinders University</td>
</tr>
<tr>
<td>Professor Joe Baker</td>
<td>Visiting Science Fellow, Agri-Science Queensland</td>
</tr>
<tr>
<td>Professor Robert Dewar</td>
<td>ANU</td>
</tr>
<tr>
<td>Dr John Söderbaum</td>
<td>ACIL Tasman Pty Ltd</td>
</tr>
<tr>
<td>Professor Julio Soria</td>
<td>Monash University</td>
</tr>
<tr>
<td>Professor Stephen Buckman</td>
<td>ANU</td>
</tr>
<tr>
<td>Professor John Howard</td>
<td>ANU</td>
</tr>
<tr>
<td>Professor Halina Rubenstein-Dunlop</td>
<td>University of Queensland</td>
</tr>
<tr>
<td>Professor Marcela Bilek</td>
<td>University of Sydney</td>
</tr>
<tr>
<td>Dr Brian James</td>
<td>Chair, Technical Reference Committee</td>
</tr>
<tr>
<td>Dr Frank Bruhn</td>
<td>AINSE</td>
</tr>
<tr>
<td>Ms Uyen Nguyen (secretary)</td>
<td>ANU</td>
</tr>
</tbody>
</table>
IV.3 ANU Facility Staff

**Academic Staff**
Professor John Howard BSc PhD Sydney, FInstP
Professor Robert Dewar BSc Melb, MSc Melb, PhD Princeton, FAA
Dr Boyd Blackwell BSc PhD Sydney
Dr Cormac Corr PhD Belfast
Dr Matthew Hole BSc BE PhD Sydney
Dr Greg von Nessi BSc Massachusetts PhD
Dr Graham Dennis PhD ANU
Dr Michael Fitzgerald PhD, Sydney
Dr Clive Michael PhD ANU

**Professional Staff**
Dr Horst Punzmann BSc Regensburg, PhD
Mr Michael Blacksell
Dr Fenton Glass BSc Queensland PhD
Mr Mark Gwynneth
Ms Uyen Nguyen
Dr David Pretty BSc Melb PhD
Dr Bernhard Seiwald Dipl.Ing. Graz Uni. of Tech., Mag. Uni. of Graz, PhD Graz Uni. of Tech.
Mr John Wach (Finished in December 2012) BAppSci CAE Ball, GradDipEl CCAE

**Postgraduate Students**
Mr Farzand Abdullatif
Mr George Bowden
Mr Craig Bowie
Mr Juan Caneses
Mr Haitao Chen
Mr Sebastien Cox
Mr Lei Chang
Mr Benjamin Frost
Mr Shaun Haskey
Mr Ashley Gibson
Ms Romana Lester
Mr Mathew McGann
Ms Aimee Nizette
Mr Zhisong Qu
Mr Cameron Samuell
Ms Nandika Thapar
Mr Matt Thompson
Mr Alexander Thorman
Mr Callan Cain

**Honours Students**
Mr Ka-Jin Chan
Ms Karen Short
Summer Scholars
Mr James McKay
Mr Marthinus Jacobs
Michael Cromer
Ms Adelle Wright

PhB/Advanced Studies
Mr Ciaron Quinlivan
Miss Sabina Scully

Visiting Overseas Students
Ms Aude Petin, University Paris sud-11
Mr Zhai Yang, Nanjing University of Science and Technology
Mr Peter Urlings, Eindhoven University of Technology
V. GRANTS AWARDED

Department of Innovation, Industry, Science and Research

B Blackwell, RL Dewar, M Hole, J Howard, H Punzmann
Plasma Fusion Education Investment Fund Project
2010-2013 $7,000,000

Australian Research Council

Hole M, Dewar R, McClements K, Pinches SD, Sharapov S
2010 Discovery Project Grant
_Burning Plasmas: resolving energetic particle physics for ITER_
2010-2012 $285,000

Hole M, Dewar R, Dendy R O., Hudson S R, Blackwell B, Escande D
2011 Discovery Project Grant
_Emergence and control of self-organisation in fusion plasmas: through ITER and beyond”_
2011-2013 $255,000

Corr C
2010 Future Fellowships Grant
_The plasma boundary: a major challenge for fusion science and material technology for ITER and beyond_
2010-2014 $680,552

Hole, Appel, Blackwell, De Bock, Dewar, Howard, Martin, Michael, Nuehrenberg, Scannell, Svensson, Wisse
International Science Linkages Competitive Grant
_Model/data fusion: using Bayesian inversion to constrain equilibrium and stability theory of advanced magnetic confinement experiments ahead of the International Thermonuclear Experimental Reactor_
2008-2012 $395,051

Hole M
2009 Future Fellowships Grants
_Fusion Energy and the Physics of Burning Plasmas_
2009-2013 $686,400

Howard J.
_Towards a steady-state fusion reactor: Understanding and controlling eruptive instabilities in tokamak_
2012-2014 $430,000

Scholarships, Travel and Teaching Grants
Blackwell B.
*From Stellarator to tokamaks: The effects of 3D structure on Alfven eigenmodes*
2010-2012 (ANSTO) $39,000

Chang L.
*From Helicon discharges to fusion plasmas: dynamics of wave-particle-plasma interaction between electromagnetic modes*
2012-2013 (AINSE) $7,500

Haskey S.
*From Stellarators to Tokamaks: The Effects of 3D Structure on Alfven Eigenmodes*
2010-2012 (AINSE) $4,920

Hole M.
*Making waves – in symmetry breaking fusion plasma*
2011-2012 (DAAD/G8) $13,000

Hole M.
*Scoping TAE excitation using NBI*
2011-2012 (ANSTO) $1,800

Howard J.
*Imaging Motional Stark Effect for internal current measurements*
2011-2012 (AINSE) $1,800
VI. PROJECT PROGRESS VERSUS MILESTONES

All Milestones are shown. Milestone order has been changed with the agreement of the Department, some being delayed and some moved ahead, as can be seen by the numbers which refer to the original agreement. Overall progress is a little ahead of the original agreement apart from the last four project milestones, which were delayed with the agreement of the Department.

Project Milestones

<table>
<thead>
<tr>
<th>Milestone Order</th>
<th>Description</th>
<th>Original Milestone Date</th>
<th>Achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sign Agreement</td>
<td>22 December 2009</td>
<td>✓</td>
</tr>
<tr>
<td>2</td>
<td>Finalise Detailed Facility Infrastructure Upgrade Schedule</td>
<td>6 January 2010</td>
<td>✓</td>
</tr>
<tr>
<td>3</td>
<td>Put new Radio Frequency system out to tender</td>
<td>31 March 2010</td>
<td>✓</td>
</tr>
<tr>
<td>4</td>
<td>Define scope of Fire Protection upgrade in Plant and Machine Area</td>
<td>31 March 2010</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Submit Annual Business Plan 1</td>
<td>31 March 2010</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Submit Milestone Report 1</td>
<td>31 March 2010</td>
<td>✓</td>
</tr>
<tr>
<td>5</td>
<td>Select Radio Frequency System Supplier</td>
<td>30 June 2010</td>
<td>✓</td>
</tr>
<tr>
<td>6</td>
<td>Define Data Access and Metadata Format</td>
<td>30 June 2010</td>
<td>✓</td>
</tr>
<tr>
<td>7</td>
<td>Launch new Website</td>
<td>30 June 2010</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Submit Milestone Report 2</td>
<td>30 June 2010</td>
<td>✓</td>
</tr>
<tr>
<td>8</td>
<td>Commission new server for H-1NF Data storage</td>
<td>30 September 2010</td>
<td>✓</td>
</tr>
<tr>
<td>9</td>
<td>Finalise performance indicators</td>
<td>30 September 2010</td>
<td>✓</td>
</tr>
<tr>
<td>10</td>
<td>Create database for Summary Data in a more generally accessible form (Metadata)</td>
<td>30 September 2010</td>
<td>✓</td>
</tr>
<tr>
<td>11</td>
<td>Commission high speed camera (imaging system) for investigating short time scale phenomena</td>
<td>30 September 2010</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Submit Annual Report 1 (including Milestone Report 3)</td>
<td>30 September 2010</td>
<td>✓</td>
</tr>
<tr>
<td>12</td>
<td>Commission new fast timer and trigger system</td>
<td>31 March 2011</td>
<td>✓</td>
</tr>
<tr>
<td>14</td>
<td>Complete Data System Interface for the Coherence Imaging Camera</td>
<td>31 March 2011</td>
<td>✓</td>
</tr>
<tr>
<td>17</td>
<td>Commission Current Controller to provide more flexible access to various plasma configurations.</td>
<td>31 March 2011</td>
<td>✓</td>
</tr>
<tr>
<td>20</td>
<td>First plasma produced in satellite prototype</td>
<td>31 March 2011</td>
<td>✓</td>
</tr>
<tr>
<td>22</td>
<td>Specify Components required for the Vacuum System Upgrade</td>
<td>31 March 2011</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Submit Annual Business Plan 2</td>
<td>31 March 2011</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Submit Milestone Report 5</td>
<td>31 March 2011</td>
<td>✓</td>
</tr>
<tr>
<td>Original</td>
<td>Description</td>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Create a database of Magnetic Configurations</td>
<td>30 June 2011</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Decommission radio frequency source and begin installation of the upgraded sources</td>
<td>30 June 2011</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Commission Spectral Line Monitors dedicated to monitoring specific impurities (e.g. C, O)</td>
<td>30 June 2011</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Submit Milestone Report 6</td>
<td>30 June 2011</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Demonstration of initial diagnostics on Satellite Device</td>
<td>30 September 2011</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Submit Annual Report 2 (including Milestone Report 7)</td>
<td>30 September 2011</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Upgrade multi-channel interferometer - Phase I complete</td>
<td>31 December 2011</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Commission new Radio Frequency Heating Antenna</td>
<td>31 December 2011</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Demonstrate operation of new Radio Frequency Heating System (source and antenna)</td>
<td>31 December 2011</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Submit Milestone Report 8</td>
<td>31 December 2011</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Extend the Magnetic Database to include plasma effects</td>
<td>31 March 2012</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Coherence Imaging Camera upgrade complete</td>
<td>31 March 2012</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>First RF plasma in Satellite Device</td>
<td>31 March 2012</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Submit Annual Business Plan 3 and Milestone Report 9</td>
<td>31 March 2012</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Remote operation from Sydney University → ANSTO</td>
<td>30 June 2012</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Key diagnostics automation complete</td>
<td>30 June 2012</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Commission upgraded High Voltage Electrical Supply Bay to required standard</td>
<td>30 June 2012</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Submit Milestone Report 10</td>
<td>30 June 2012</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Complete integration of Current Controller</td>
<td>30 September 2012</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>New Thermionic Source/Biasing Electrode Operational</td>
<td>30 September 2012</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Submit Annual Report 3 (including Milestone Report 11)</td>
<td>30 September 2012</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Install/upgrade internal vacuum components</td>
<td>31 December 2012</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Complete upgrade to Interferometer - Phase 2 complete</td>
<td>31 December 2012</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Submit Milestone Report 12</td>
<td>31 December 2012</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Commission Final Form of Satellite Material Device</td>
<td>31 March 2013</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Commission High Resolution Spectroscopic Imaging System</td>
<td>31 June 2013</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Commission new Vacuum Pump Systems</td>
<td>30 September 2013</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Submit Annual Business Plan 4 and Milestone Report 13</td>
<td>30 September 2013</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Integration of systems for vacuum quality improvement</td>
<td>30 September 2013</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Diagnostic Upgrade complete</td>
<td>31 December 2013</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Demonstrate integration of upgraded systems and access to new regimes</td>
<td>31 December 2013</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Submit Final Report 30 September 2013</td>
<td>31 July 2014</td>
<td></td>
</tr>
</tbody>
</table>
VII. FINANCIAL STATEMENTS

Statements are provided for EIF funds, and for the remaining part of the MNRF funding (over). Signed originals of the final statements have been provided directly to the Department by ANU central Audits.

STATEMENT OF INCOME AND EXPENDITURE
For the Period 01 July, 2012 to 30 June, 2013

Current Period $

Overspent Balance as at 01 July, 2012 (567,466.14)

Add
Other Income 2,000,000.00
Investment Income 1,595.75
Total Income 2,001,595.75

Total Available Funds Before Expenditure 1,434,129.61

Less
Salaries & Related Costs 508,827.70
Equipment - Capital 103,193.87
Equipment - Non-Capital 105,438.78
Utilities & Maintenance 110.99
Travel Field & Survey Expenses 162.27
Expendable Research Materials 56,545.38
Other Expenses 318,281.19
Total Expenditure 1,092,560.18

Unspent Balance as at 30 June, 2013 341,569.43

I certify that the above statement accurately summarises the financial records of the grant and that these records have been properly maintained so as to record accurately the Income and Expenditure of the grant.

Professor Ian Young
Vice-Chancellor
The Australian National University

Dr. Elizabeth Eadie
Acting Director
Corporate Governance & Risk

3/10/13

See over page for a breakdown according to categories in the EIF funding agreement.
EIF breakdown according to categories in Agreement

<table>
<thead>
<tr>
<th>Income and Expenditure Statement 2012/2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma Fusion Education</td>
</tr>
<tr>
<td>Funds Allocated</td>
</tr>
<tr>
<td>Income</td>
</tr>
<tr>
<td>EIF Cash Contribution</td>
</tr>
<tr>
<td>EIF Cash Contribution Interest</td>
</tr>
<tr>
<td>Total Income</td>
</tr>
<tr>
<td>Expenditure</td>
</tr>
<tr>
<td>Facility Infrastructure and Upgrade</td>
</tr>
<tr>
<td>Project Management</td>
</tr>
<tr>
<td>Plasma Heating</td>
</tr>
<tr>
<td>Data Access</td>
</tr>
<tr>
<td>Plasma Diagnostics</td>
</tr>
<tr>
<td>Advanced Operation</td>
</tr>
<tr>
<td>Infrastructure Replacement</td>
</tr>
<tr>
<td>Total Expenditure</td>
</tr>
<tr>
<td>Operating result</td>
</tr>
<tr>
<td>Previous years carry forward</td>
</tr>
<tr>
<td>Unspent Cash Balance</td>
</tr>
</tbody>
</table>

Note that much of the equipment originally budgeted under "Infrastructure Replacement" has been more appropriately classified as upgrade and therefore appears under "Advanced Operation" capability.

MNRF Residual Account: Cash flow Report

STATEMENT OF INCOME AND EXPENDITURE
For the Period 01 July, 2012 to 30 June, 2013

<table>
<thead>
<tr>
<th>Movement (Actuals + Financial)</th>
<th>Adjustments</th>
<th>Current Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unspent Balance as at 01 July, 2012</td>
<td>220,932.38</td>
<td>(57,543.38)</td>
</tr>
<tr>
<td>Add</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfer from other Income</td>
<td>7,860.32</td>
<td>(7,860.32)</td>
</tr>
<tr>
<td>Investment Income</td>
<td>3,846.67</td>
<td>(1,780.65)</td>
</tr>
<tr>
<td>Total Income</td>
<td>11,706.99</td>
<td>(9,640.97)</td>
</tr>
<tr>
<td>Total Available Funds Before Expenditure</td>
<td>$232,639.37</td>
<td>($67,184.35)</td>
</tr>
<tr>
<td>Less</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salaries &amp; Related Costs</td>
<td>32,389.94</td>
<td>(32,389.94)</td>
</tr>
<tr>
<td>Equipment - Non-Capital</td>
<td>233.19</td>
<td>0.00</td>
</tr>
<tr>
<td>Scholars Expenses</td>
<td>52,546.21</td>
<td>(34,794.41)</td>
</tr>
<tr>
<td>Travel Field &amp; Survey Expenses</td>
<td>23,645.44</td>
<td>0.00</td>
</tr>
<tr>
<td>Other Expenses</td>
<td>6,547.21</td>
<td>0.00</td>
</tr>
<tr>
<td>Total Expenditure</td>
<td>115,361.99</td>
<td>(67,184.35)</td>
</tr>
<tr>
<td>Unspent Balance as at 30 June, 2013</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**ACRONYMS**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>Australian Broadcasting Commission</td>
</tr>
<tr>
<td>AFRG</td>
<td>Australian Fusion Research Group</td>
</tr>
<tr>
<td>ANU</td>
<td>Australian National University</td>
</tr>
<tr>
<td>AINSE</td>
<td>Australian Institute of Nuclear Science and Engineering</td>
</tr>
<tr>
<td>ANSTO</td>
<td>Australian Nuclear Science and Technology Organisation</td>
</tr>
<tr>
<td>CDX-U</td>
<td>Current Drive Experiment-Upgrade</td>
</tr>
<tr>
<td>COSNet</td>
<td>Complex Open Systems Research Network</td>
</tr>
<tr>
<td>CQU</td>
<td>Central Queensland University</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DISR</td>
<td>Department of Industry, Science and Resources</td>
</tr>
<tr>
<td>DRM</td>
<td>Digital Radio Mondial</td>
</tr>
<tr>
<td>DSTO</td>
<td>Defence Science and Technology Organisation</td>
</tr>
<tr>
<td>DT</td>
<td>Deuterium-Tritium</td>
</tr>
<tr>
<td>ECH</td>
<td>Electron Cyclotron Heating</td>
</tr>
<tr>
<td>ECRH</td>
<td>Electron Cyclotron Resonance Heating</td>
</tr>
<tr>
<td>ELSI</td>
<td>Electronically Swept Interferometer</td>
</tr>
<tr>
<td>FEIT</td>
<td>Faculty of Engineering and Information Technology</td>
</tr>
<tr>
<td>GAE</td>
<td>Global Alfvén eigenmode</td>
</tr>
<tr>
<td>GAM</td>
<td>Geodesic Acoustic Mode</td>
</tr>
<tr>
<td>H-1NF</td>
<td>H-1 (Heliac) National Facility</td>
</tr>
<tr>
<td>IAS</td>
<td>Institute of Advanced Science</td>
</tr>
<tr>
<td>ITER</td>
<td>International Fusion Experiment</td>
</tr>
<tr>
<td>JET</td>
<td>Joint European Torus</td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
</tr>
<tr>
<td>LHD</td>
<td>Large Helical Device</td>
</tr>
<tr>
<td>MAST</td>
<td>Mega-Ampere Spherical Tokamak</td>
</tr>
<tr>
<td>MEMS</td>
<td>Micro-Electronic Mechanical Switch</td>
</tr>
<tr>
<td>MDF</td>
<td>Materials Diagnostic Facility</td>
</tr>
<tr>
<td>MDS</td>
<td>Model Data System</td>
</tr>
<tr>
<td>MHD</td>
<td>Magneto-hydrodynamic</td>
</tr>
<tr>
<td>MOSS</td>
<td>Modulated Optical Solid State</td>
</tr>
<tr>
<td>NIFS</td>
<td>National Institute for Fusion Science</td>
</tr>
<tr>
<td>OVMS</td>
<td>Open Virtual Machine Operating System</td>
</tr>
<tr>
<td>ORION</td>
<td>Oak Ridge Ion</td>
</tr>
<tr>
<td>PIN</td>
<td>P-type (intrinsic layer) n-type diode</td>
</tr>
<tr>
<td>RF</td>
<td>Radio-frequency</td>
</tr>
<tr>
<td>RIEFP</td>
<td>Research Infrastructure Equipment and Facilities Scheme</td>
</tr>
<tr>
<td>SOFT</td>
<td>Spread-Spectrum Optical Fourier Transform</td>
</tr>
<tr>
<td>SPIRT</td>
<td>Strategic Partnerships with Industry - Research and Training Scheme</td>
</tr>
<tr>
<td>SP3</td>
<td>Space Plasma and Plasma Processing</td>
</tr>
<tr>
<td>TFTR</td>
<td>Tokamak Fusion Test Reactor</td>
</tr>
<tr>
<td>TJ-II</td>
<td>Torus de la Junta de l'Energia Nuclear, the second device (a Heliac)</td>
</tr>
<tr>
<td>UKAEA</td>
<td>United Kingdom Atomic Energy Authority</td>
</tr>
<tr>
<td>UC</td>
<td>University of Canberra</td>
</tr>
<tr>
<td>VNC</td>
<td>Virtual Network Computer</td>
</tr>
<tr>
<td>WiMAX</td>
<td>Worldwide Interoperability for Microwave Access</td>
</tr>
<tr>
<td>WKB</td>
<td>Wentzel-Kramers-Brillouin</td>
</tr>
</tbody>
</table>