Artemis operational statistics

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This year was a shortened year of user access in Artemis, as the decommissioning phase of the Artemis upgrade project began in November 2018. The team delivered six user experiments over seven slots, totalling 15 weeks of access with five setup weeks. As well as the user experiments, the team delivered two weeks of development with external collaborators and three weeks of preparatory work for design of the 100 kHz beamline as part of the upgrade. Figure 2 shows the schedule for the year.

Experiments

Three of the experiments used the atomic and molecular physics (AMO) chamber. All three used the velocity map imaging (VMI) detector, but for different experimental techniques: photoelectron circular dichroism, coulomb explosion imaging and ultrafast photoelectron spectroscopy. The VMI was swapped for a time of flight spectrometer during the ultrafast photoelectron spectroscopy experiment, to collect data at a different energy range. The three remaining experiments were carried out using the angle resolved photoemission chamber for studying condensed matter samples. Typically, a week of setup is dedicated to each experiment before users arrive. Similar experiments are grouped together to minimise setup time.

Facility performance and reliability

Figure 1 shows the availability and reliability calculations for the 2018-19 year. We run the laser continuously from Mondays through to Fridays during experiments, and regularly carry on data-taking over weekends. In this calculation, the availability for unsupported data-taking overnight and at weekends is weighted equally with supported hours. Laser reliability through the half year of user experiments was very good and we were able to recover the two experiments we lost due to problems in the previous year.

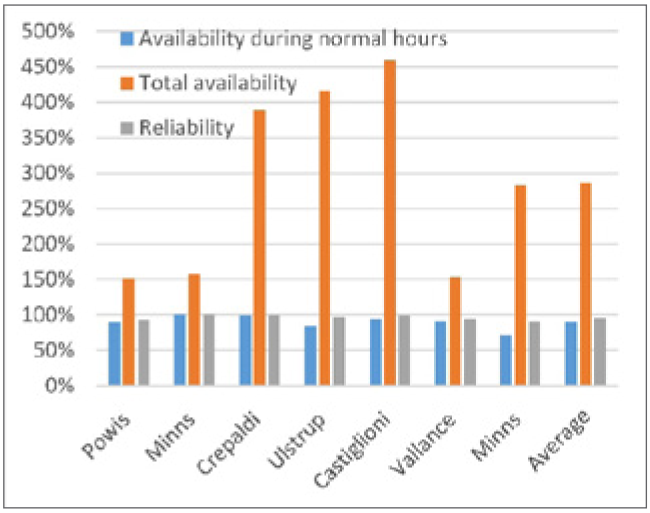

Figure 1: Artemis availability and reliability for user experiments in 2018-19

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Week Beginning	Experiment
02/04/2018	Setup for Powis
09/04/2018	Powis 17220004
16/04/2018	Time of Flight Install
23/04/2018	Setup for Minns
30/04/2018	
07/05/2018	Minns 17220009
14/05/2018	
21/05/2018	AMO chamber removal & MatSci chamber install
28/05/2018	
04/06/2018	Setup for Crepaldi & Ulstrup
11/06/2018	Crepaldi 17120003
18/06/2018	
25/06/2018	Ulstrup 17220002
02/07/2018	
09/07/2018	Setup for Castiglioni
16/07/2018	Castiglioni 17220007
23/07/2018	
30/07/2018	Laser Service
06/08/2018	Setup for Vallance
13/08/2018	Vallance 17120001
20/08/2018	
27/08/2018	TOPAS service
03/09/2018	
10/09/2018	Minns 17220009
17/09/2018	
24/09/2018	Few Cycle Idler Development
01/10/2018	
08/10/2018	
15/10/2018	100 kHz HHG tests
22/10/2018	
29/10/2018	
05/11/2018	
12/11/2018	
19/11/2018	
26/11/2018	
03/12/2018	
10/12/2018	
17/12/2018	
24/12/2018	
31/12/2018	
07/01/2019	Artemis lab move to RCaH
14/01/2019	
21/01/2019	
28/01/2019	
04/02/2019	
11/02/2019	
18/02/2019	
25/02/2019	
04/03/2019	
11/03/2019	
18/03/2019	
25/03/2019	

Figure 2: Artemis Schedule for 2018-19

Gemini operational statistics

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During the reporting year, April 2018 – April 2019, a total of seven complete experiments were delivered in the Gemini Target Area and two experiments in TA2. In total 33 high power laser experimental weeks were delivered in the Gemini Target Area and 20 weeks in TA2. The delivered schedule is presented in Figure 2.

The availability of the Gemini laser system (delivery to the Gemini Target Area) was 86% during normal working hours, rising to 143% with time made up from running out of normal working hours. The reliability of the Gemini laser was 91%. TA2 availability was 88% during normal working hours, rising to 142% with time made up from running out of normal working hours. An individual breakdown of the availability and reliability for the experiments conducted is presented in Figure 1.

The high levels of total availability were made possible by the continued unique operational model employed on Gemini, which involves running the laser late into the evening. In addition, frequent weekend operational days were made available.

As well as the delivered experimental schedule, a system access slot was scheduled to demonstrate the Active beam stabilization on the Gemini South beam (see Annual Report article by Dann *et al*. for further details).

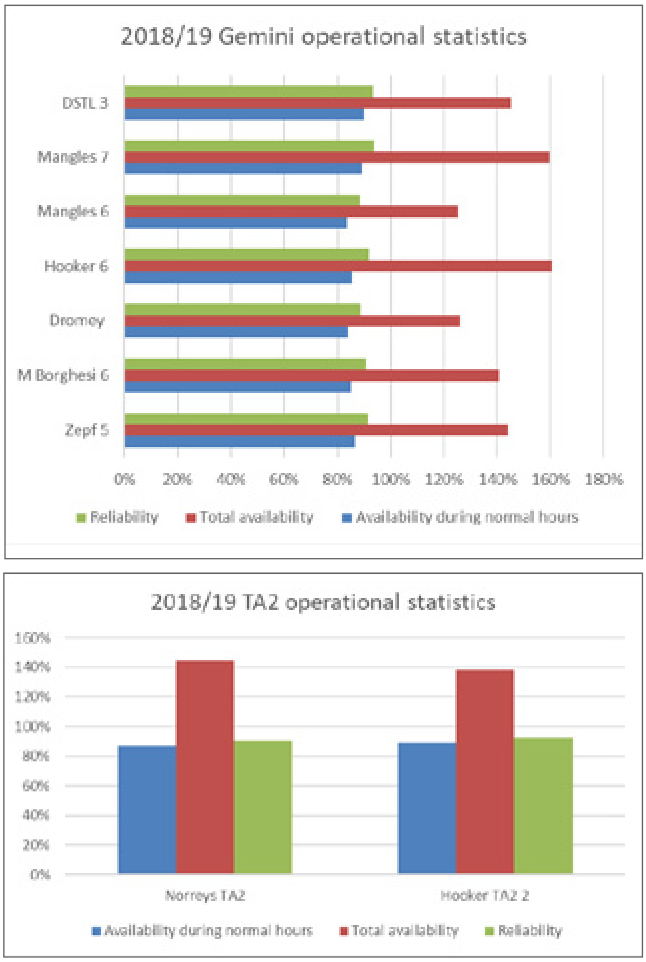

Figure 1: 2018/19 Gemini/TA2 operational statistic

Week beginning	Gemini	TA2
02/04/2018		
09/04/2018	Beamline switchover	
16/04/2018		
23/04/2018	Zepf	Hooker (part 2)
30/04/2018	17210015	17210008
07/05/2018		
14/05/2018		
21/05/2018	XPW	
28/05/2018	Grating change	
04/06/2018		
11/06/2018	Plasma mirror setup	
18/06/2018		
25/06/2018		Hooker (part 3)
02/07/2018	Borghesi	17210008
09/07/2018	17210027	
16/07/2018		
23/07/2018		
30/07/2018	Beamline setup	
06/08/2018		
13/08/2018	Dromey	
20/08/2018	18110012	Norreys (part 1)
27/08/2018		18110024
03/09/2018		
10/09/2018		
17/09/2018	Pulse train setup	
24/09/2018		
01/10/2018		
08/10/2018	Hooker	
15/10/2018	18110004	Norreys (part 2)
22/10/2018		18110024
29/10/2018		
05/11/2018	Quantel service	
12/11/2018	Hooker ctd.	
19/11/2018		
26/11/2018	System access	
03/12/2018	Beam stabilisation	System access
10/12/2018		
17/12/2018		
24/12/2018	Christmas 2018	
31/12/2018		
07/01/2019	Mangles	
14/01/2019	17210011	
21/01/2019	Mangles	
28/01/2019	18110023	
04/02/2019		
11/02/2019	Maintenance	
18/02/2019		
25/02/2019	Commercial access	
04/03/2019	18220000	
11/03/2019		
18/03/2019		
25/03/2019		

Figure 2: 2018/19 Gemini/TA2 operational schedule

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Octopus and Ultra Operational Statistics

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Octopus facility

In the reporting period (April 2018 to March 2019), 54 unique User groups submitted a total of 76 proposals bidding for time at the Octopus facility. 42 experiments comprising 104 weeks access time were awarded and delivered to the UK User community throughout the year. A full breakdown of number of weeks applied for versus number of weeks scheduled is shown in Figure 1, indicating an oversubscription ratio of 1.97:1. Figure 3 shows that Biology and Bio-materials formed the majority of applications.

There were a total of 22 formal reviewed publications recorded throughout the year.

Ultra facility

In the reporting period (April 2018 to March 2019), 30 unique User groups submitted a total of 46 proposals bidding for time at the Ultra facility. 26 experiments comprising 60 weeks access time were awarded and delivered to the UK User community. A full breakdown of number of weeks applied for versus number of weeks scheduled is shown in Figure 2, indicating an oversubscription ratio of 1.8:1. Figure 4 shows that Chemistry formed the majority of applications.

There were a total of 19 formal reviewed publications recorded throughout the year.

User satisfaction

The average User satisfaction marks obtained from the scheduled Octopus and Ultra Users are shown in Figure 5, with an average satisfaction of 88% across the categories. There was a total of 53 hours downtime reported over the combined 164 weeks of access.

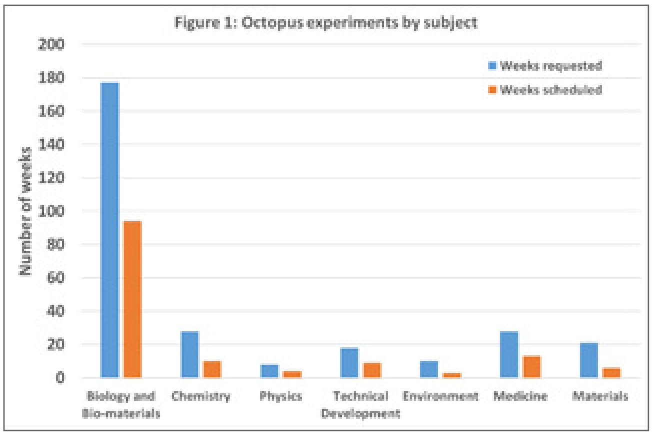

Figure 1: Octopus experiments by subject

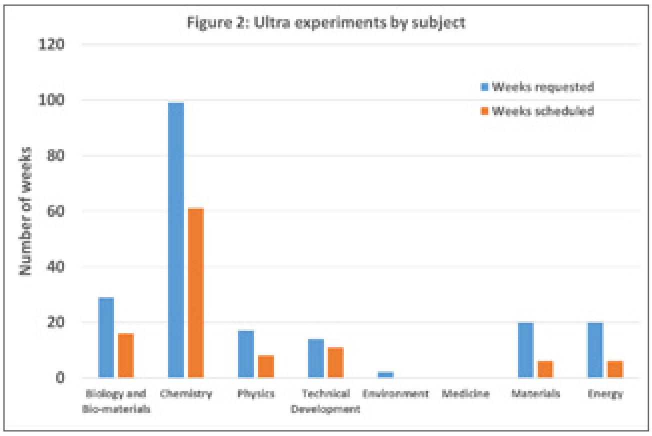

Figure 2: Ultra experiments by subject

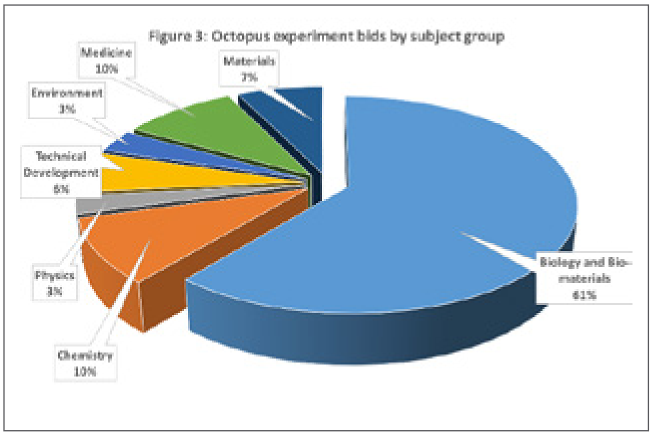

Figure 3: Octopus experiment bids by subject group

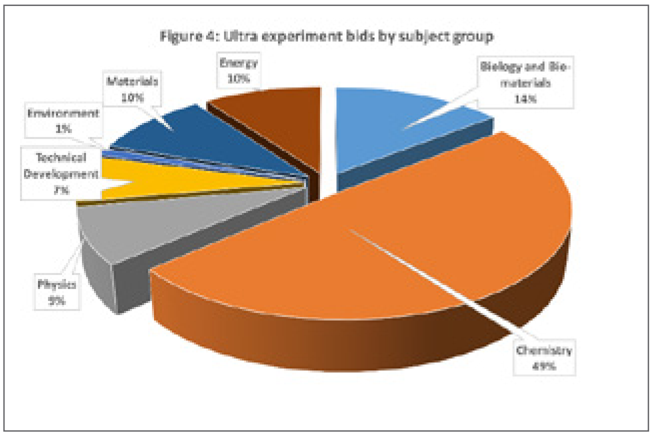

Figure 4: Ultra experiment bids by subject group

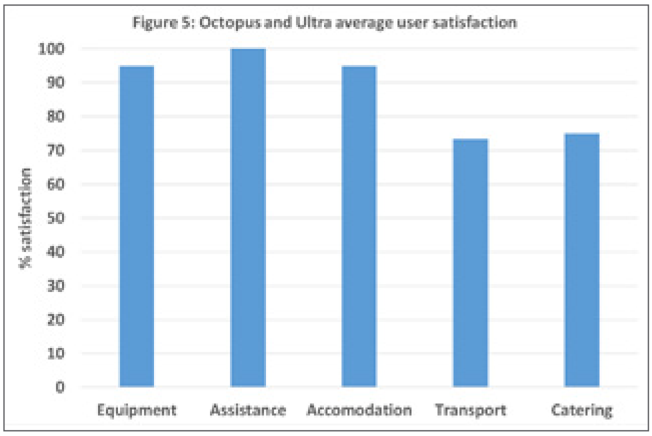

Figure 5: Octopus and Ultra average user satisfaction

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Target Fabrication Operational Statistics

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Experimental Support

This paper details Target Fabrication support given to experimental groups in the Vulcan target areas TAW and TAP, along with those in the Gemini Target Area, between April 2018 and April 2019. Target Fabrication supported seven solid target Vulcan experiments and three solid target Gemini experiments, totalling 40 weeks of Vulcan access (plus training weeks) and 20 weeks of Gemini access. Additional experiments were also supported for filters and other diagnostic elements, which are non-trivial but not reported on in these statistics. At 60, the total number of weeks supported is less than the previous year (71 in 2017-2018), but more than 2016-2017 (56) and 2015-2016 (57)

The Target Fabrication Group also supported academic access experiments at AWE and internal experiments.

From this reporting year onwards, Gemini and Vulcan targets will be separated out for tables and graphics. This is due to Gemini targets being produced in arrays or tapes: with multiple shots available per object delivered, each position on the array or tape will now be referred to as an individual target. Quantifying these together with Vulcan single-shot targets disproportionately skews analysis. When it comes to target types, Gemini almost exclusively requires ultra-thin films which, although they are processed similarly to Vulcan targets, end up being used very differently in the experiment.

This report does not include support for other areas of the CLF, including Artemis and the LSF.

	Experiment	Total Targets Produced	Class 1	Class 2	Class 3
VULCAN	0418 TAW	44	8		36
	0718 TAW	21	10		11
	0818 TAP	141	57	84	
	1118 TAW	93	93		
	1118 TAP	123	67	56	
	0119 TAW	321	231		86
	0319 TAW	229	39		190
	Total	**972**	**505**	**140**	**323**
GEMINI	0818 GTA	1116	1116		
	Total	**1116**			

Table 1: Targets produced by experiment and their relative complexity, with Class 1 being 'standard' targets and Class 3 requiring the most resources

1) Supported experiments

For the reporting year, the total number of targets produced for each experiment is shown in Table 1. This year, to better understand the amount of resources required for each experiment, a classification of complexity has been introduced: Class 1 targets require no R&D and have been fabricated before; Class 2 targets require some short-term R&D and/or complex manufacture processes; Class 3 targets require long-term R&D using multiple technologies, with detailed characterisation to verify, and are also referred to as "high-specification targets".

The total number of targets supplied to target areas at RAL by the Group this reporting year is 2088, 972 for Vulcan and 1116 for Gemini. This reporting year saw greater complexity of requirements, with fewer low-complexity thick-foil targets produced and multiple experiments requiring low-quantity, high-complexity targets. The number of high specification targets increased to 323 from 119 last reporting year and 98 in 2016-2017.

2) Experimental Response

It is seen as a significant strength of Target Fabrication to be rapidly responsive to experimental results and conditions by working collaboratively with user groups. The Group responds to experimental changes during a campaign, and often implements a number of modifications or redesigns to the original requests. The number of modifications and variations on each experiment differs and is dependent on the type of experiment and also on external conditions, such as diagnostic and laser performance.

Target Fabrication's Quality Management System (QMS) ensures that there is tracking of all targets that are modified in some way from the initial design. These are targets that were delivered, but were not initially defined on the approved target list: this includes modifications to approved designs or completely new requests during the campaign. It is important to note this capability to change designs can often ensure experimental success. For the reporting year the data on modified targets is shown in Chart 1.

Chart 1 shows that this reporting year had far fewer modified requests compared to previous years; good evidence that the experiments in this reporting year ran more-or-less to plan. As mentioned in the operational statistics for last year, there were four experiments that involved drastic changes early in the period and required >60% modifications. The reduction in modifications compared to previous years can be explained by the number of experiments that had high levels of complexity and therefore flexibility was impractical.

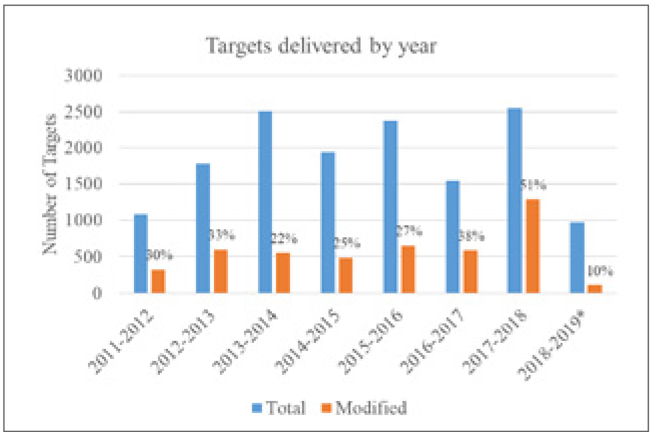

Chart 1: Total targets delivered by year, with the percentage of those that were modified from initial agreed deliverables. This reporting year only Vulcan targets are included. For Gemini, no modifications were required to the 1116 targets delivered. Modified targets include any target that did not appear on the agreed target list.

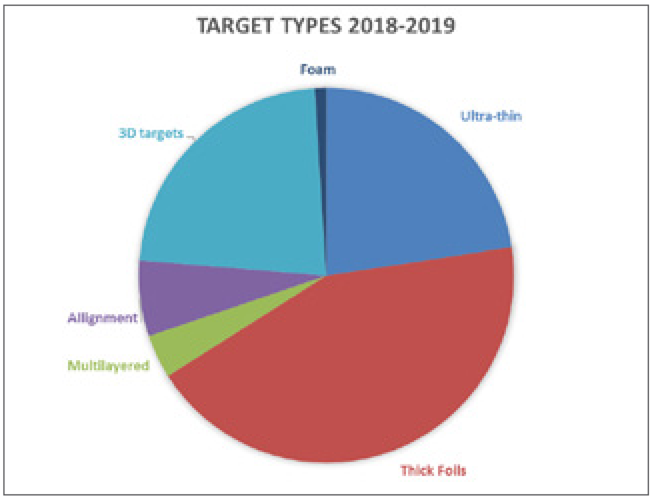

Chart 2: Target types for 2018-2019 delivered to Vulcan

3) Target Categories

Targets can be separated into seven main categories as shown in Table 2 and Chart 2.

Ultra-thin foil targets are specified as having a thickness <500 nm, and require a coating capability and a skilled fabricator to process; thick foils make up the rest of single component foils. Multilayer foils are stacks or layers of foils that require thin film coating capability to deposit multiple layers onto an existing foil; they are often different composition layers with different thicknesses. Alignment targets are specified as wires or pinholes that are used for set-up purposes. 3D micro-structures are complex 3D geometries that combine multiple fabrication techniques with skilled assembly.

In contrast to last year, this year had more high-complexity experiments. Demand for targets requiring coating capability has remained consistently high throughout the previous five years.

It should be noted that Chart 2 is not a reflection of staff effort, because assembly time for a single thick foil target is relatively short, whereas for a batch of 3D targets, trials, manufacture and characterisation activities can amount to weeks of effort.

Target Category	**2018–2019**	**2017–2018**	**2016–2017**	**2015–2016**	**2014–2015**
Ultra-thin Foil	104	485	449	197	530
Thick Foils	438	1208	743	1349	708
Multi-layered Foils	38	577	237	605	500
Alignment	66	159	78	110	85
3D Micro-structures	229	73	38	99	82
Foam/Mass-limited	10	47	0	11	0
TOTAL (Vulcan)	**972***	**2551**	**1546**	**2371**	**1937**

*Table 2: Target type by year. *Only Vulcan targets are recorded in this total. Gemini targets totalled 1116, all of which were were ultra-thin foils.*

4) Adapting to Demand

Experiments usually require similar targets with varying thickness, composition or geometry; for example, a thin foil experiment typically requests a thickness scan of a particular material. In such experiments, each thickness or composition change requires a separate thin-film coating run. Experiments using 3D targets are such that each geometry change requires a new assembly set up. Each new target thickness or geometry is designated a unique target variation.

This reporting period, within the total of 972 targets for Vulcan, there were 220 unique target variations, which averages around five targets per variation. Last reporting year the average number of targets per variation was around 7; a similar average to the two previous years. The number of target variations is a good measure of how complex an experiment is: for example, the 0119 TAW Neely experiment had one target variation accounting for over 60 targets and was therefore a relatively low complexity experiment; the 0418 TAW Read experiment had only 44 targets delivered and averaged two targets per variation, a good example of a low total number of targets but high effort experiment. The flexibility provided by the Group to provide such variability is a key capability of the CLF and enables the user community to fully utilize the limited time that is available during each experiment.

5) Waste Reduction

Unexpected delays or changes during an experiment often result in a number of targets that have been fabricated but that are not used by the end of experimental campaign. Un-shot targets in this reporting period totalled 114, accounting for 10% of the total targets made. The comparison with previous years can be seen in Chart 3 below. A value of 10% is considered an acceptable amount of surplus manufacture: the nature of experiments means that complications are hard to anticipate and the number of targets requested is based on a best-case scenario.

Any un-issued or returned targets are carefully sorted, and high specification targets are stored under closely controlled conditions for potential use on future experiments. Where possible, all spare target components and mounts are also stored for future use. The variety of mounts and components held in stock contributes to the Group's ability to adapt target designs quickly in response to experimental changes. Target Fabrication also continued to use its new 3D printing capability to manufacture the majority of target posts, both reducing costs and improving adaptability and responsiveness.

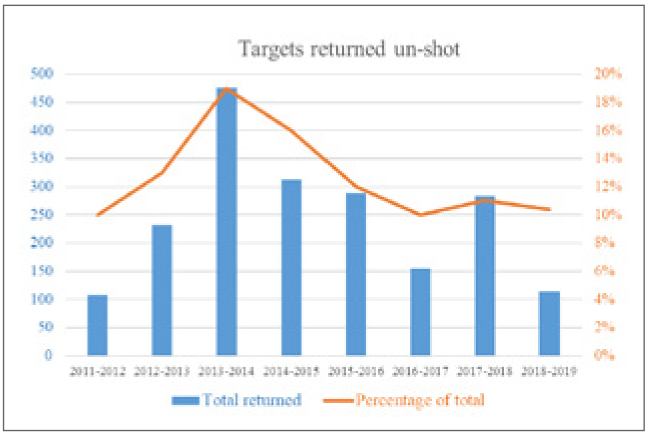

Chart 3: Total number of targets returned un-shot in blue. The orange line shows the returned targets as a percentage of total targets delivered in that reporting year.

There has been a noticeable reduction in waste since the implementation of the ISO9001 QMS, which has allowed the Target Fabrication Group to plan experimental delivery of targets in a more structured way. The improved planning processes enable long-term delivery projects to be managed effectively. It should be noted that this has not led to less flexibility, as the percentage of modified and re-designed targets is in line with the figures for before QMS implementation (2009-2010, 2010-2011).

Only 0.6% of targets were returned as non-conforming under the QMS, compared to 1% last reporting period, and 3% the preceding year. It should be noted that accurate reporting is difficult, because these are often just captured as "returned un-shot". Work is ongoing to ensure user groups record targets that do not meet their requirements as "non-conforming", rather than simply requesting additional targets. Over the last year, Target Fabrication has made a concerted effort to ask user groups to record non-conformities, but this did not translate into any more being recorded. Based on these results, it is possible that the non-conformity and returned un-shot numbers are truly representative, and that users are simply overestimating the number of shots and requesting too many targets. Targets that do not meet specifications are vetted as part of the manufacturing process and are simply not delivered.

Orion Academic Access

The Target Fabrication Group has continued to support and supply targets to the Orion Academic Access campaign. In the reporting year, targets were delivered to an experiment led by Queen's University Belfast investigating ion and neutron beam production. This experiment used a combination of ultra-thin foils and complex coil targets that required a large amount of fabrication time and effort. A final total of 64 complex targets were delivered and a number of targets were made during the experimental run, which added resource demand on the programme. The targets required the integration of a range of complex assembly and characterisation capabilities across STFC, including collaboration with the Technology Department for the manufacture of precision coils and Scitech Precision Ltd for the laser machining of target components.

External Contracts

Scitech Precision Ltd (a spinout company from the Central Laser Facility) provides high power laser targets and micro engineering solutions to the high power laser community and supplies targets, specialist coatings, laser machining services and consultancy across the world. In the year 2018-2019, a total of 35 unique customers were supplied with 126 contracts. Of these contracts, 58% were for high power laser targets, 34% for laser micromachining, 7% for phase plates, and 1% for MEMS based contracts (not target related). The spread of contracts is similar to the previous year, with approximately one-third of the business being laser machining support for the Harwell Campus, including Diamond Light Source, and a number of spin out and spin in companies. Target contracts were delivered to large scales facilities including experiments carried out on the Orion laser at AWE, LMJ in France, SG-II in China and LLE in the US.

Summary

Target Fabrication has supported eight experiments in the CLF and 12 in other international facilities in the last year, as well as providing an increasing amount of characterisation services and acting as a knowledge base for target fabrication activities throughout Europe.

The total number of targets delivered was fewer than the previous three reporting years, largely due to this year containing multiple high-complexity experiments. This year has seen three-times the number of high-specification targets delivered compared to last year. The average number of target iterations further showed how complex this year's delivery was, with around five targets per variation.

The number of modifications to target requests was at an encouraging level; 5% compared to 50% last year.

Demand for thin-films requiring coating plant capability was slightly lower than last reporting year, but has remained relatively high showing that coatings are a key capability for the facility.

References

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Vulcan Operational Statistics

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Introduction

Vulcan has completed an active experimental year, with 35 full experimental weeks allocated to target areas TAW and TAP between April 2018 and March 2019.

Table 1 shows the operational schedule for the year, and reports the shot rate statistics for each experiment.

Numbers in parentheses indicate the total number of full energy laser shots delivered to target, followed by the number of these that failed and the percentage of successful shots. The second set of numbers shows the availability of the laser to target areas during normal operating hours and including outside hours operations.

PERIOD	TAW	TAP
2018		
16 Apr – 20 May	M Read *An all-optical platform for magnetized high energy density physics research* (37, 11, 70.3%) (86.5%, 99.3%) (5 weeks)	
23 Jul – 30 Sep	Z Najmudin *Development of a bright betatron backlighter for Vulcan Target Area West* (87, 14, 83.9%) 65.4%, 105.6%) (6 weeks + 2 weeks, 2 days overrun)	
03 Sep – 21 Oct		D Margarone *Brilliant, fast neutron source employing cryogenic ribbons of solid deuterium* (86, 10, 88.4%) (91.0%, 139.7%) (5 weeks + 1 week overrun)
12/05 Nov – 09 Dec	L Gizzi Role of laser plasma interactions in the shock ignition regime (48, 18, 62.5%) (86.5%, 114.6%) (4 weeks + 3 day overrun (Sat,Sun,Mon))	G Hicks (McKenna) *Laser-solid interaction physics at intensities up to 1022W/cm2 and tight focusing conditions* (73, 13, 82.2%) (85.2%, 96.5%) (5 weeks)
2019		
14 Jan – 17 Feb	D Neely *Intense THz field-driven lattice dynamics probed with ultrafast X-ray diffraction* (125, 28, 77.6%) (86.3%, 109.9%) (5 weeks + Saturday overrun)	
04 Mar – 07 Apr	S Kar *All-optical staged acceleration of proton beams using helical coils* (151, 19, 80.8%) (85.7%, 109.3%) (5 weeks)	

Table 1: Experimental schedule for the period April 2018 – March 2019

(Total shots fired, failed shots, reliability)
(Availability normal, additional hours)

The total number of full disc amplifier shots that have been fired to target this year is 607. Table 2 shows that this figure is less than in the four previous years. 113 shots failed to meet user requirements. The overall shot success rate to target for the year is 81%, compared to 88%, 91%, 90% and 86% in the previous four years. Figure 1 shows the reliability of the Vulcan laser to all target areas over the past five years.

	No of shots	Failed shots	Reliability
14–15	1087	133	88%
15–16	1143	108	91%
16–17	948	93	90%
17–18	934	132	86%
18–19	607	113	81%

Table 2: Shot totals and proportion of failed shots for the past five years

The shot reliability to TAW is 80%, down 3% from the previous year. The shot reliability to TAP is 86% - down from 92% in 2017-18.

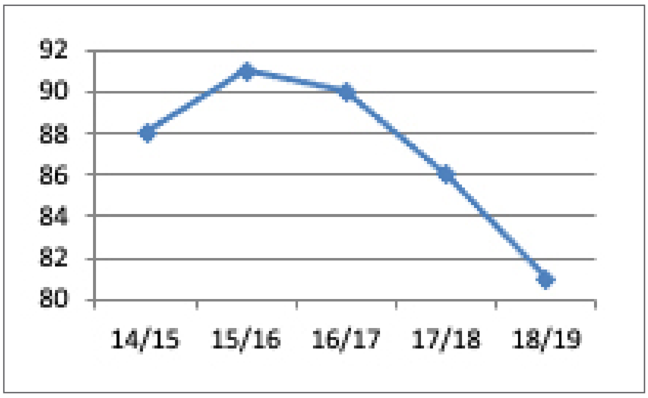

Figure 1: All areas shot reliability for each year 2014-15 to 2018-19.

Analysis of the failure modes reveals that, as in recent years, the two overriding causes of failed shots are beam alignment and front end related issues. These two causes are manifested in low or high energy output of the rod amplifier chain (outside of +/-20% of the requested energy). Approximately three-quarters of failed shots are due to this cause. Investigation into the reasons for this instability have revealed the following :

1. Instability in the pulse energy is introduced during propagation from the front end room to the laser area
2. There is a discrepancy in the pulse energy measured at the end of the rod chain during a test (rod chain) shot and a full energy (disc amplifier) shot.

Instability is particularly evident in the short pulse beamlines to TAW (seeded by the Insight laser). Additional measures are being taken to improve stability including installing diagnostics to monitor stability - specifically additional near- and far-field cameras - securing of optics and testing a fast beam stabilization scheme.

There is a requirement which was originally instigated for the EPSRC FAA that the laser system be available, during the five week periods of experimental data collection, from 09:00 to 17:00 hours, Monday to Thursday, and from 09:00 to 16:00 hours on Fridays (a total of 195 hours over the five week experimental period). The laser has not always met the startup target of 9:00 am but it has been common practice to operate the laser well beyond the standard contracted finish time on several days during the week. In addition, the introduction of early start times on some experiments continues to lead to improvements in availability.

On average, Vulcan has been available for each experiment to target areas for 85.1% of the time during contracted hours, compared with 77.2% for the previous year. Although this figure is a considerable improve-ment, the overall availability to all target areas has only slightly increased from 111.5% in 2017-18 to 112.9%. The time that the laser is unavailable to users is primarily the time taken for beam alignment at the start of the day.

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