Artemis Operational Statistics

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The Artemis team delivered a total of nine user experiments from April 2017 to March 2018, as well as three weeks of development projects in partnership with facility users and three weeks of internal development. In total, we delivered 21 weeks of user access and eight weeks of dedicated experiment setup. Table 1 shows the schedule for the year.

Experiments

Three of the nine experiments conducted used the angle resolved photoemission chamber for studying condensed matter samples. Two further experiments were carried out using the spin time of flight chamber in conjunction with condensed matter samples. Three further experiments utilised the AMO chamber, two using velocity map imaging for coulomb explosion imaging and photoelectron circular dichroism, the third using the time of flight detector for photoelectron spectroscopy. The one remaining experiment used the polychromatic beamline with a flat-field spectrometer and multiple gas targets. The Artemis team dedicates approximately one week of set-up to each experiment before users arrive. Similar experiments are grouped together, to minimize set-up time.

Facility performance and reliability

Figure 1 shows the availability and reliability calculations for the 2017-18 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. The experiments for Crepaldi and Vallance were rerun in the 2018-2019 year due to the laser failures in this year.

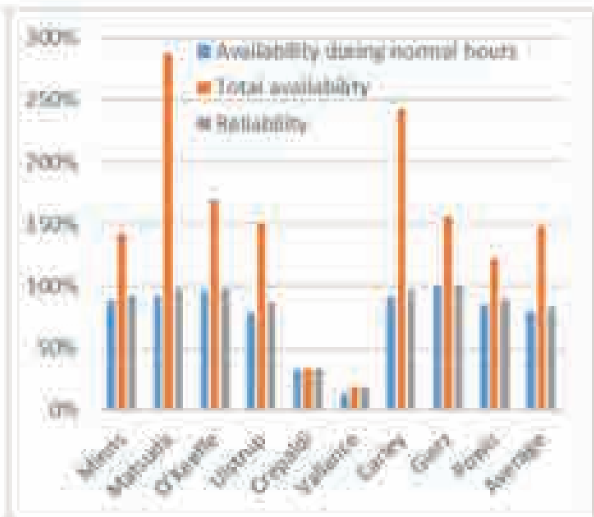

Figure 1: Artemis availability and reliability for user experiments in 2017-18.

Week Beginning	Experiment
03/04/2017	Minns 16120015
10/04/2017	Setup for Minns
17/04/2017	Few Cycle Idler Development
24/04/2017	Toroidal Mirror Upgrade
01/05/2017	TOPAS Service
08/05/2017	Minns 16120015
15/05/2017	
22/05/2017	Setup for Matsuda
29/05/2017	Matsuda 17120002
05/06/2017	
12/06/2017	HHG tests at 1700 nm
19/06/2017	Ptychography Development
26/06/2017	Laser Service
03/07/2017	Few Cycle Idler Development
10/07/2017	Laser repair
17/07/2017	Laser Amplifier Upgrade
24/07/2017	
31/07/2017	Setup for O'Keeffe
07/08/2017	O'Keeffe 17120006
14/08/2017	
21/08/2017	
28/08/2017	
04/09/2017	Artemis User meeting
11/09/2017	Setup for Ulstrup
18/09/2017	Ulstrup 17120000
25/09/2017	
02/10/2017	Crepaldi 17120003
09/10/2017	Laser repair
16/10/2017	Ulstrup 17120000
23/10/2017	HHG tests at 1700 nm
30/10/2017	AMO Installation
06/11/2017	Setup for Vallance
13/11/2017	Vallance 17120001
20/11/2017	Laser repair
27/11/2017	
04/12/2017	Laser service
11/12/2017	HHG tests at 1700 nm
18/12/2017	Maintenance
25/12/2017	
01/01/2018	Setup for Carley
08/01/2018	TOPAS Service
15/01/2018	Carley 16120022
22/01/2018	
29/01/2018	Setup for Gierz
05/02/2018	Gierz 17220003
12/02/2018	
19/02/2018	
26/02/2018	Spin TOF Removal
05/03/2018	AMO Installation
12/03/2018	Setup for Powis
19/03/2018	Powis 17220004
26/03/2018	

Figure 2: Artemis Schedule for 2017-2018

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Gemini Operational Statistics

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During the reporting year, April 17 – April 18, a total of eight complete experiments were delivered in the Gemini Target Area and two experiments in TA2. In total 34 high power laser experimental weeks were delivered the Gemini Target Area and 18 weeks to 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 140% with time made up from running out of normal working hours. The reliability of the Gemini laser was 91%. 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.

One system access slot was fielded during the year to demonstrate the HAMS target positioning system in the Gemini Target Area.

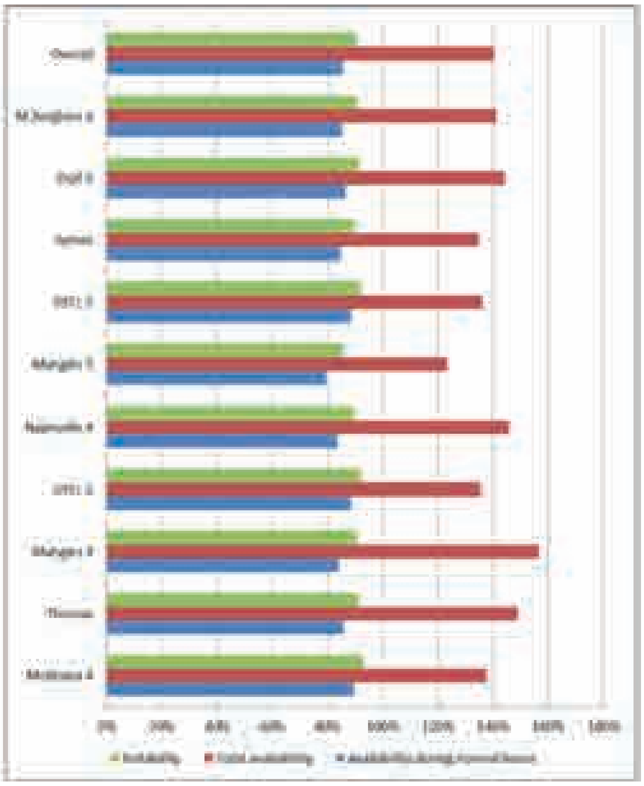

Figure 1: 2017/18 Operational statistics.

Week beginning	Gemini	TA2
03/04/2017		
10/04/2017	System Access	
17/04/2017	HAMS	
24/04/2017		
01/05/2017	Changeover	
08/05/2017		
15/05/2017	McKenna	
22/05/2017	[illegible]	
29/05/2017		
05/06/2017		
12/06/2017		
19/06/2017	Maintenance	
26/06/2017		
03/07/2017		
10/07/2017		
17/07/2017	Thomas	Brenner part 1
24/07/2017	[illegible]	17110022
31/07/2017		
07/08/2017		
14/08/2017	Mangles	
21/08/2017	[illegible]	
28/08/2017	Changeover	
04/09/2017		
11/09/2017	Commercial Access	
18/09/2017	[illegible]	Brenner part 2
25/09/2017		17110022
02/10/2017		
09/10/2017	Maintenance	
16/10/2017		
23/10/2017		
30/10/2017	Najmudin	Brenner Part 3
06/11/2017	[illegible]	17110022
13/11/2017		
20/11/2017		
27/11/2017	Changeover	
04/12/2017		
11/12/2017	Commercial Access	
18/12/2017	[illegible]	
25/12/2017	Christmas	Christmas
01/01/2018		
08/01/2018	Commercial Access	
15/01/2018	[illegible]	
22/01/2018	Joint magnet	
29/01/2018	Set up	
05/02/2018		
12/02/2018	Mangles	Hooker part 1
19/02/2018	[illegible]	17210008
26/02/2018		
05/03/2018		
12/03/2018	Changeover	
19/03/2018	Zepf	Hooker part 2
26/03/2018	[illegible]	17210008

Figure 2: 2017/18 Gemini operational schedule

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Octopus and Ultra Operational Statistics

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Octopus facility

In the reporting period (April 2017 to March 2018), 58 unique User groups submitted a total of 69 proposals bidding for time at the Octopus facility. 36 experiments comprising 89 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 2.16:1. Figure 3 shows that Biology and Bio-materials formed the majority of applications.

There were a total of 17 formal reviewed publications recorded throughout the year.

Ultra facility

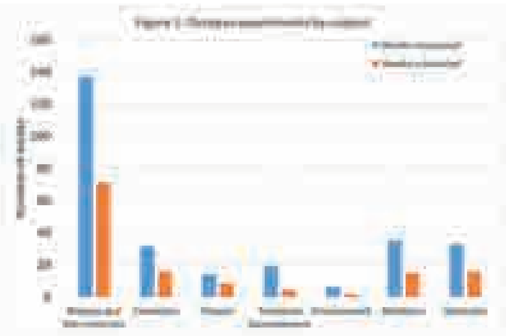
In the reporting period (April 2017 to March 2018), 21 unique User groups submitted a total of 29 proposals bidding for time at the Ultra facility. 21 experiments comprising 58 weeks access time were awarded and delivered to the UK User community. A full breakdown of number of weeks applied for versus number of weeks scheduled is shown in Figure 2 indicating an oversubscription ratio of 1.21:1. Figure 4 shows that Chemistry formed the majority of applications.

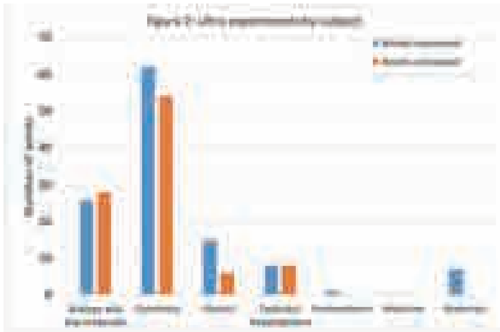
There were a total of 21 formal reviewed publications recorded throughout the year.

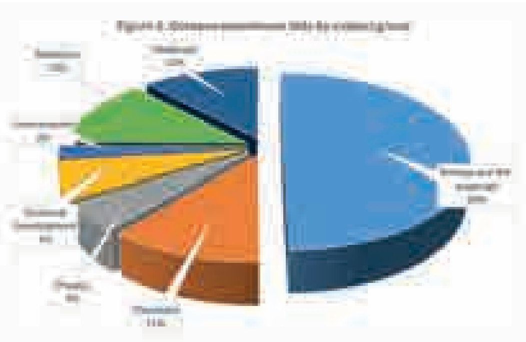
In addition, there were 12 publications recorded by individual merit scientists working in the Lasers for Science Facility.

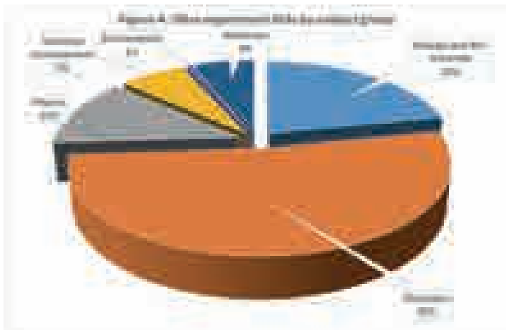
User satisfaction

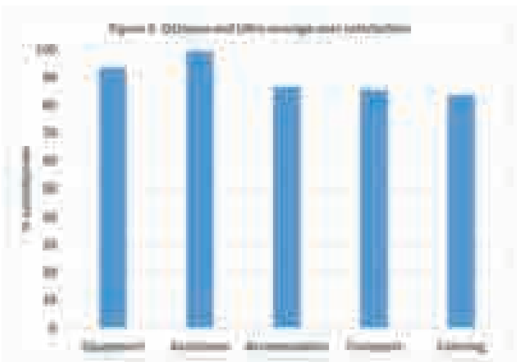
The average User satisfaction marks obtained from the scheduled Octopus and Ultra Users are shown in Figure 5, with an average satisfaction of 89.7% across the categories. In total, 80 hours downtime were reported over the combined 147 weeks of access.











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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, as well as the Gemini Target Area, between April 2017 and April 2018. Target Fabrication supported 11 solid target Vulcan experiments and four solid target Gemini experiments, totalling 55 weeks of Vulcan access (plus training weeks) and 16 weeks of Gemini access. Gemini experiments were also supported for filters and other diagnostic elements, which are non-trivial but not reported on in these statistics. The total number of weeks supported is greater than that for the last two years: 71 compared to 56 (2016-2017) and 57 (2015-2016).

The Target Fabrication group also supported academic access experiments at AWE and internal experiments, such as the April 2017 HAMS campaign.

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

1) Target Numbers

For the reporting year, the total number of targets produced for each experiment is shown in Table 1. High specification targets are defined as targets that have taken significant staff research and development time, or approximately more than ten times the effort of a typical target.

The total number of targets supplied to target areas at RAL by the group this reporting year is 2551 compared to 1546 last reporting year, 2371 in 2015-2016 and 1937 in 2014-2015.
This reporting year saw a large number of requests for high-quantity low-complexity foil targets, which explains the large increase on last year. The number of high specification targets increased to 119 from 98 last reporting year and 87 in 2014-2015.

Experiment	Targets Produced	No. of High-spec Targets	Modified Targets (% of total)
0517 TAW	391	26	91%
0617 TAW	303		
0717 GTA	51	3	27%
0717 TAP	121	17	7%
0817 GTA	209		56%
0817 TAP	68	30	
0817 TAW	175		48%
1017 GTA	12		
1017 TAP	34		
1017 TAW	174		77%
0118 TAP	352		
0118 TAW	156	43	78%
0218 GTA	27		41%
0318 TAP	125		
0318 TAW	353		74%
TOTAL	**2551**	**119**	**50.5%**

Table 1: Target production summary for 2017-2018. High-specification targets include 3D micro-structures, low density targets and mass limited targets. Modified targets are not in the pre-approved target list and the number incorporates modifications to approved designs and additional requests.

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 Target Fabrication 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 is variable, dependent on the type of experiment and also on experimental conditions, such as diagnostic and laser performance.

Target Fabrication's Quality Management System enables tracking of the targets delivered and whether they are modified from the initial design during the run. This is a useful metric as it gives an idea of the extra resources needed to support an experiment. For the reporting year, data is shown in Table 1. These are targets that were delivered but were not initially defined on the approved target list; this includes modifications to designs or completely new requests during the campaign. It is important to note this capability to change designs can often ensure experimental success.

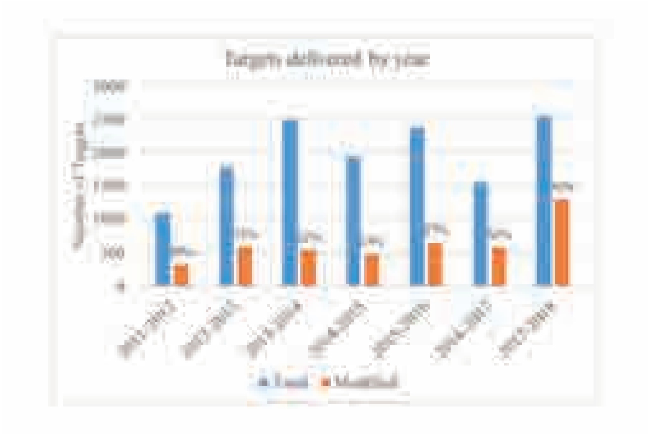

Chart 1: Totals targets delivered by year. Also included is the number of targets modified in some way from original requests.

Chart 1 shows that this reporting year, for the first time, modified targets account for the majority of targets delivered. As shown in Table 1, five of the 15 supported experiments had over 50% of targets modified; these five experiments had significant changes made during the campaigns due to unforeseen circumstances and were largely responsible for the high target total. In the last reporting period, there were four experiments where over 50% of targets were modified. Although the total number of modified targets significantly increased this period, the number of experiments supported with significant changes was similar to last period. It should be noted that the vast majority of experiments ran more or less to the agreed target list and required few modifications, as shown in Table 1.

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, 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; there 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 require skilled assembly or micro-machining to produce them.

Target Category	2017-2018	2016-2017	2015-2016	2014-2015
Ultra-thin Foil	485	449	197	530
Thick Foils	1208	743	1349	708
Multi-Layered Foils	577	237	605	500
Alignment	159	78	110	85
3D Micro-structures	73	38	99	82
Mass-limited	47	0	11	0
TOTAL	**2551**	**1546**	**2371**	**1937**

Table 2: Target type by year. Ultra-thin foils and multi-layered foils require thin-film coating capability. 3D Microstructures require skilled manual fabrication. Mass-limited requires MEMS capability.

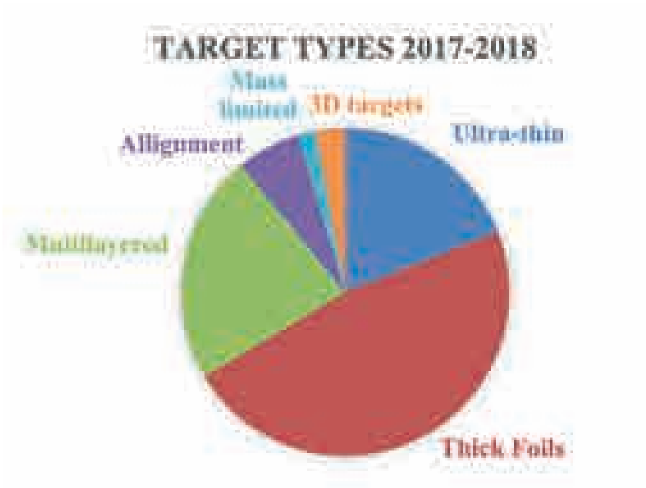

Chart 2: Target types for 2017-2018. This year included a number of high-quantity low complexity thick-foil experiments.

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.

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.

This reporting period, within the total of 2551 targets, there were 371 unique target variations which averages seven targets per variation. Last reporting year the average number of targets per variation was six (277 total), the same average as the two previous years.

'Number of target variations' is a good measure of how complex an experiment is: for example, 0617 TAW experiment had one target variation accounting for over 200 targets and was therefore a relatively low complexity experiment; the 0817 TAP experiment averaged two targets per variation and was an 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 284, accounting for 11% of the total targets made. The comparison with previous years is shown in Chart 3 below. 2013-2014 shows the highest return rate, largely due to increased effectiveness of recording from that year forward.

Any un-issued or returned targets are carefully sorted, and

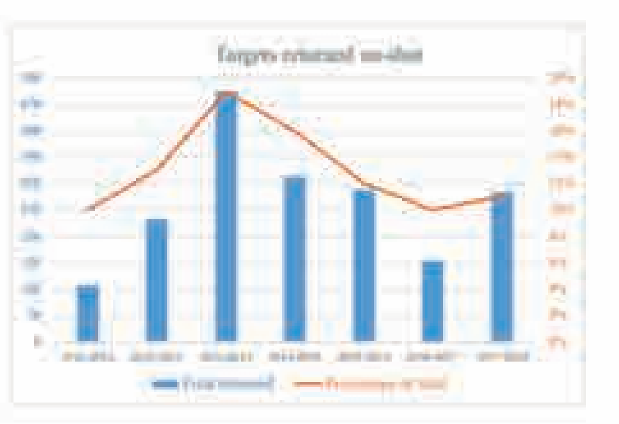

Chart 3: Total number of targets returned un-shot in blue. In orange is the returned targets as a percentage of total target delivered in that reporting year.

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 by the Target Fabrication group contributes to its ability to adapt target designs quickly in response to experimental changes. Target Fabrication also began using its new 3D printing capability to manufacture the majority of target posts, both reducing cost and improving adaptability and responsiveness.

There has been a noticeable reduction in waste since the implementation of the ISO9001 Quality Management System (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).

Fewer than 1% of targets were returned as non-conforming under the QMS, compared to 3% last reporting period. It should be noted that accurate reporting is difficult because these are often just captured as "returned un-shot". Work is ongoing to ensure that user groups record targets that do not meet their requirements as "non-conforming", rather than simply requesting additional targets.

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 a continuation of the Strathclyde-led consortium investigating proton focusing. As in the previous year, target delivery was a collaboration that included target component supply from the Technische Universität Darmstadt (TUD) and General Atomics (GA), with design, assembly and manufacture also from the CLF. A total of 11 complex targets were delivered to add to the complement of un-shot targets from the previous campaign for a single week experiment. The targets required the integration of a range of complex assembly and characterisation capabilities across the collaboration.

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 supplied targets, specialist coatings, laser machining services and consultancy across the world. In the year 2017-2018, a total of 42 unique customers were supplied with 141 contracts. Of these contracts, 57% were for high power laser targets, 29% for laser micromachining, 10% for phase plates, and 4% for MEMS based contracts (not target related). The spread of contracts is similar to the previous year, with approximately one-third of the business comprising 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 for experiments, 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 15 experiments in the CLF and eleven 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.

Total targets delivered were higher than the previous three reporting years, largely due to four low-complexity, high-quantity thick foil experiments. The number of modified targets was also very high at 50.5% of the total targets delivered, due to five of the 15 experiments requiring a large quantity of changes; it is, however, worth noting that the number of experiments with significant modifications was largely in line with previous years.

The type of targets has largely followed the same pattern over the past three years, with a large proportion (41.6%) requiring coating plant capability (multi-layered and ultra-thin foils). The complexity of experiments this reporting period has remained largely the same; individual target variations averaged seven, compared to six in the previous three years.

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Vulcan Operational Statistics

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Vulcan has completed an active experimental year, with 55 full experimental weeks allocated to target areas TAW and TAP between April 2017 and March 2018.

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 are the availability of the laser to target areas during normal operating hours and including outside hours operations.

PERIOD	TAW	TAP
2017		
08 May - 11 Jun	D Neely *Intense terahertz radiation from picosecond laser-produced plasmas* (177, 8, 95.5%) (92.4%, 117.6%) (5 weeks + one day overrun (Saturday ops))	
26 Jun - 30 Jul	S White *K-edge shifts for shock compressed matter* (101, 12, 88.1%) (77.5%, 132.1%) (5 weeks + 1 week overrun)	N Booth *Anisotropy measurements of resistive plasmas for investigating the microphysics of warm dense matter* (83, 7, 91.6%) (63.6%, 115.4%) (5 weeks + 1 week overrun)
21 Aug - 24 Sep	L Willingale *Relativistic magnetic reconnection field dynamics* (56, 16, 71.4%) (79.7%, 107.9%) (5 weeks)	K Lancaster *Production of hot dense plasmas via resistive guiding of fast electrons* (46, 1, 97.8%) (79.1%, 121.7%) (5 weeks + 3 day overrun)
09 Oct - 19/12 Nov	K Glize *Characterization of the density modulation driven by crossing beams* (59, 19, 67.8%) (77.2%, 103.7%) (6 weeks + 2 day overrun)	G Hicks *Ion acceleration from low-Z over-critical gas jets* (46, 3, 93.5%) (76.5%, 123.5%) (5 weeks + 1 week overrun)
2018		
15/08 Jan - 11 Feb	C Brenner (136, 29, 78.7%) (74.5%, 109.5%) (4 weeks + 1 week overrun)	S Kar *Advanced schemes for light-sail acceleration by employing PW pulses at moderate intensities* (86, 9, 89.5%) (70.8%, 102.7%) (5 weeks + 1 week overrun)
25 Feb/04 Mar - 01/08 Apr	M Borghesi *Thin shell instabilities in collisionless plasmas* (98, 22, 77.6%) (78.4%, 113.3%) (5 weeks + 3 day overrun)	P McKenna *Highly-efficient direct laser acceleration of electrons in self-generated magnetic channels* (47, 6, 87.0%) (78.7%, 111.6%) (5 weeks + 2 day overrun)

Table 1: Experimental schedule for the period April 2017 – March 2018.

(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 935. Table 2 shows that this figure is less than in the three previous years. 132 shots failed to meet user requirements. The overall shot success rate to target for the year is 86%, compared to 88%, 88%, 91% and 90% 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
13 - 14	1015	121	88%
14 - 15	1087	133	88%
15 - 16	1143	108	91%
16 - 17	948	93	90%
17 - 18	934	132	86%

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

The shot reliability to TAW is 83%, down 6% from the previous year. The shot reliability to TAP is 92% - down slightly from 93% in 2016-17.

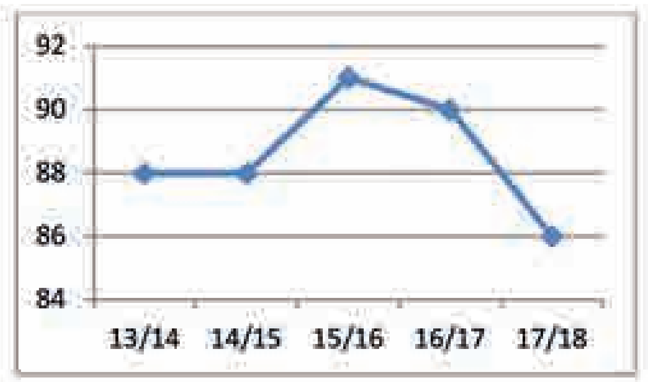

Figure 1: All areas shot reliability for each year 2013-14 to 2017-18.

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:

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.

Additional diagnostics are being installed in the laser system to monitor stability and improve performance.

There is a requirement, which was originally instigated for the EPSRC FAA, that the laser system be available from 09:00 to 17:00 hours Mondays to Thursdays, and from 09:00 to 16:00 hours on Fridays, during the five-week periods of experimental data collection (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 77.2% of the time during contracted hours, compared with 85.8% for the previous year. Although this figure is considerably down, the overall availability to all target areas has only dropped slightly from 112.4% in 2016-17 to 111.5%. 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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