Operational Statistics

Gemini Operational Statistics 2022–23

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Week beginning	
04-Apr-22	
11-Apr-22	
18-Apr-22	System Access
25-Apr-22	
02-May-22	
09-May-22	
16-May-22	
23-May-22	
30-May-22	
06-Jun-22	
13-Jun-22	
20-Jun-22	
27-Jun-22	
04-Jul-22	
11-Jul-22	Sarri
18-Jul-22	
25-Jul-22	
01-Aug-22	
08-Aug-22	
15-Aug-22	22110007
22-Aug-22	
29-Aug-22	
05-Sep-22	
12-Sep-22	
19-Sep-22	PoC Imaging
26-Sep-22	22510000
03-Oct-22	
10-Oct-22	
17-Oct-22	
24-Oct-22	
31-Oct-22	McKenna
07-Nov-22	22110009
14-Nov-22	
21-Nov-22	
28-Nov-22	
05-Dec-22	
12-Dec-22	
19-Dec-22	
26-Dec-22	
02-Jan-23	
09-Jan-23	
16-Jan-23	
23-Jan-23	Borghesi
30-Jan-23	22110011
06-Feb-23	
13-Feb-23	
20-Feb-23	
27-Feb-23	
06-Mar-23	
13-Mar-23	
20-Mar-23	Hooker
27-Mar-23	2221009

Figure 1: Gemini 2022/23 operational schedule

During the reporting year, April 22 – April 23, a total of four complete experiments were delivered in the Astra-Gemini Target Area. In total, 23 high power laser experimental weeks were delivered to the Gemini Target Area. The delivered Gemini schedule is presented in Figure 1.

The availability of the Gemini laser system (delivery to the Gemini Target Area) was 82% during normal working hours, rising to 126% with time made up from running outside of normal working hours. The reliability of the Gemini laser was 87%. An individual breakdown of the availability and reliability for the TA3 experiments conducted is presented in Figure 2.

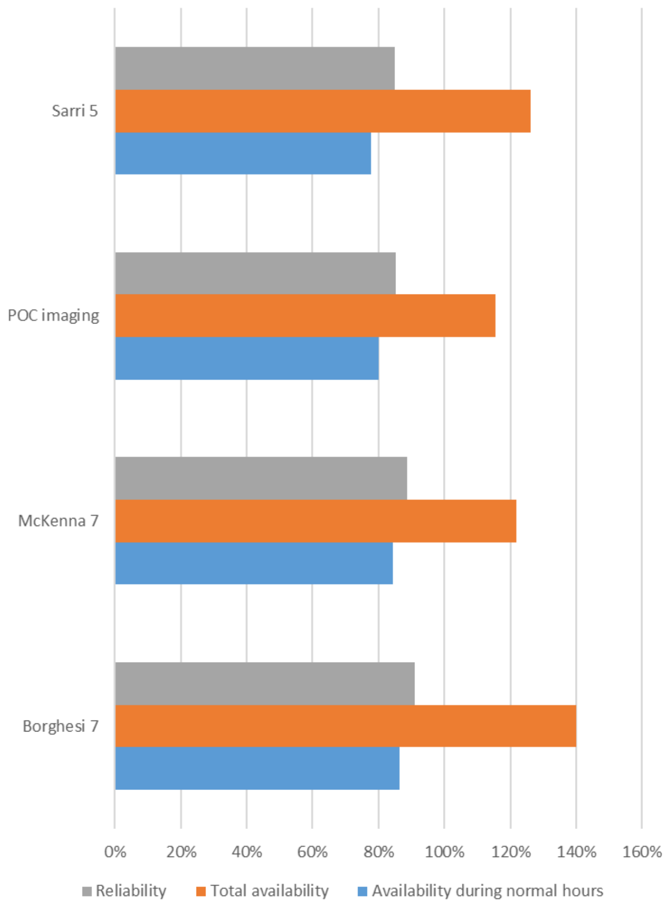

Figure 2: 2022/23 TA3 operational statistics

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.

During the system access period, the four Quanta Ray pro 350 pump lasers for amplifier 3 were replaced by eight Lumibird QSmart 1500s. This was a major infrastructure change to the Astra laser system and took a significant portion of the year. This impacted the number of delivered weeks and number of experiments conducted, while the Sarri experiment was paused to resolve some initial install issues with the new lasers.

The upgraded pump lasers for amplifier 3 provide double the pump energy, which allows for the Astra output energy to increase up to 2.0 J, and incorporates a pump homogenization scheme. This will improve the beam homogeneity, both for the Gemini amplifier seed beam and for the TA2 main beam.

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Vulcan Operational Statistics 2022/23

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Introduction

Vulcan has completed another active experimental year (April 2022 - March 2023) with 30 full experimental weeks allocated between target areas West (TAW) and Petawatt (TAP). Overall, the laser statistics show an improved operational standard with an overall reliability of 92%. Table 1 (opposite page) shows the operational schedule and statistics for this period. Information on the number of shots, energy-on-target success rate and availability hours are also provided in the table.

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.

We have operated throughout the year, with short maintenance periods. Two important developments have increased both the reliability and the availability of the laser, even with reduced staff. Firstly, turn on and off was made fully automatic, with only three buttons to press when turning off, and automatic turn on at 6:00 am without any human intervention that has worked throughout the experimental campaign. Secondly, an automatic energy stabilisation system on one of the pump lasers has not only ensured that the energy has remained stable throughout the day, but has also allowed the system to be operational earlier, since the energy has been stabilised in a shorter time.

The total number of full disc amplifier shots that have been fired to target this year is 601. Table 2 shows how this figure compares with that for the previous four years. 51 shots failed to meet user requirements. The overall shot success rate to target for the year is 92%.

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

	No of shots	Failed shots	Reliability
18–19	607	113	81%
19–20	653	102	84%
20–21	325	64	80%
21–22	604	73	88%
22–23	601	51	92%

Figure 1 shows the reliability of the Vulcan laser to all target areas over the past five years. The shot reliability to TAW is 93%, up 5% from the previous year. The shot reliability to TAP is 86%, down 1% from 87% in 2021-22.

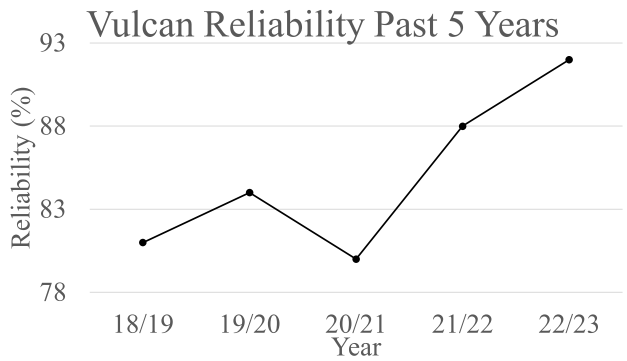

Figure 1: All areas shot reliability for each year 2018-19 to 2022-23

Uncommon shot configurations, like small energy requests or oscillator changes, have corresponded to most of the failed shots; on at least one experiment, all four oscillators changed, three of them alternately on the same beamlines.

The first experiment in TAP for about a year resulted in the lowest level of reliability. Mid-way through the second experiment, the previously mentioned automatic energy stabilisation system was implemented on the pump laser. This resulted in an increase in reliability, despite being introduced part way through the experiment.

Availability has been reduced by problems with the high voltage part of the system, in rod or disk amplifier elements.

Table 1: Experimental schedule for the period April 2022 – March 2023

Period	TAW	TAP
2022		
9 May – 12 Jun	J Fuchs Investigation of the ion streaming instability in the laboratory and of the associated energy transfer to the background plasma (Shots 129, Failed 6, Reliability 95.3%) (Availability 94.6%, w extra hours 108.0%) (5 weeks) 20110000	
12 Sep – 15 Oct	L Gizzi Impact of Laser Bandwidth on Laser-Plasma Interaction in Shock Ignition Relevant Conditions (Shots 55, Failed 6, Reliability 89%) (Availability 94%, w extra hours 111.3%) (5 weeks) 22110010	
31 Oct – 3 Dec	DSTL Commercial Beam-time (Shots 184, Failed 9, Reliability 95.1%) (Availability 98.3%, w extra hours 117.8%) (5 weeks) 22510001	C Palmer Energetic proton beam collimation in long scale length plasmas (Shots 100, Failed 17, Reliability 83%) (Availability 96.9%, w extra hours 117.2%) (5 weeks) 22210010
2023		
23 Jan – 25 Feb	P McKenna Measuring the role of anisotropic heating and plasma expansion on relativistic self-induced transparency (Shots 73, Failed 6, Reliability 91.8%) (Availability 95%, w extra hours 112.3%) (5 weeks) 22110008	D Carroll Investigation of EMP emissions for understanding the source mechanisms and the rules for tuning and employing them in high power lasers (Shots 60, Failed 7, Reliability 88.3%) (Availability 95.5%, w extra hours 112.8%) (5 weeks) 19210019

Throughout the year, there were 11 failures on elements on the disk amplification chain/capacitor bank, and two on the rod amplification chain. Each time there was a problem with these elements, it took between three hours and one-and-a-half days to resolve.

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, Monday to Thursday, 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 mainly 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 to target areas for each experiment for 95.7% of the time during contracted hours, compared with 77.3% for the previous year. The overall availability to all target areas has increased slightly to 113.2%, compared with 112.9% in 2021-22. 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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Lasers for Science Facility Operational Statistics 2022/23

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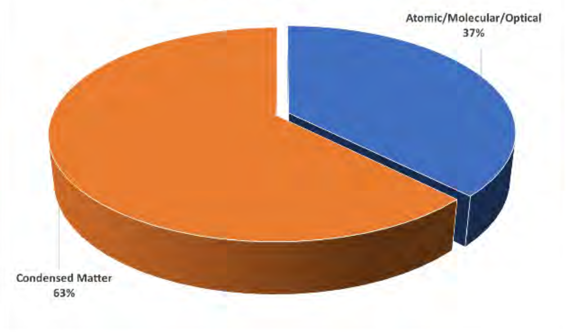
Artemis facility

During this reporting period, the UK User community applied for 24 weeks of peer-reviewed access to the Artemis facility, of which 12 weeks were awarded, representing an over-subscription ratio of 2.00. A total of seven unique User groups performed eight scheduled experiments. Figure 1 shows that Condensed Matter was the most popular experiment subject conducted.

A total of 182 hours of downtime and 1390 additional hours of access were reported, corresponding to a total of 48 weeks of access time delivered to the User Community.

Figure 1: Artemis experiments by subject



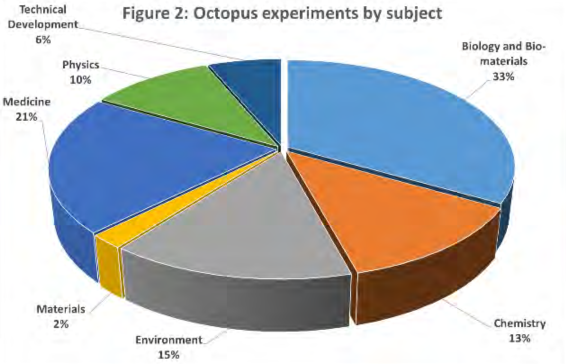
Octopus facility

During this reporting period, the UK User community applied for 158 weeks of peer-reviewed access to the Octopus facility, of which 90 weeks were awarded, representing an over-subscription ratio of 1.76. A total of 30 unique User groups performed 30 scheduled experiments. In addition, a total of 13 days proof of concept experiments and five days of commercial access were delivered. Figure 2 shows that Biology and Bio-materials was the most popular experiment subject conducted.

A total of 153 hours of downtime and 13 additional hours of access were reported.

A total of 19 formal reviewed publications were recorded through the year.

Figure 2: Octopus experiments by subject

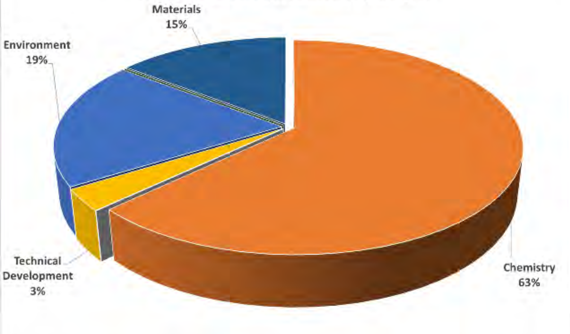


Ultra facility

During this reporting period, the UK User community applied for 75 weeks of peer-reviewed access to the Ultra facility, of which 50 weeks were awarded, representing an over-subscription ratio of 1.50. A total of 17 unique User groups performed 21 scheduled experiments. In addition, a total of 6.5 days proof of concept experiments, 11 days collaborative access and 15 days commercial access were delivered. Figure 3 shows that Chemistry was the most popular experiment subject conducted.

A total of 70 hours of downtime and 643 additional hours of access were reported. There were a total of 19 formal reviewed publications recorded through the year.

Figure 3: Ultra experiments by subject



User satisfaction feedback

Surveys completed by User groups after their experimental time indicated an average satisfaction rating of 91.4% over the five specified categories.

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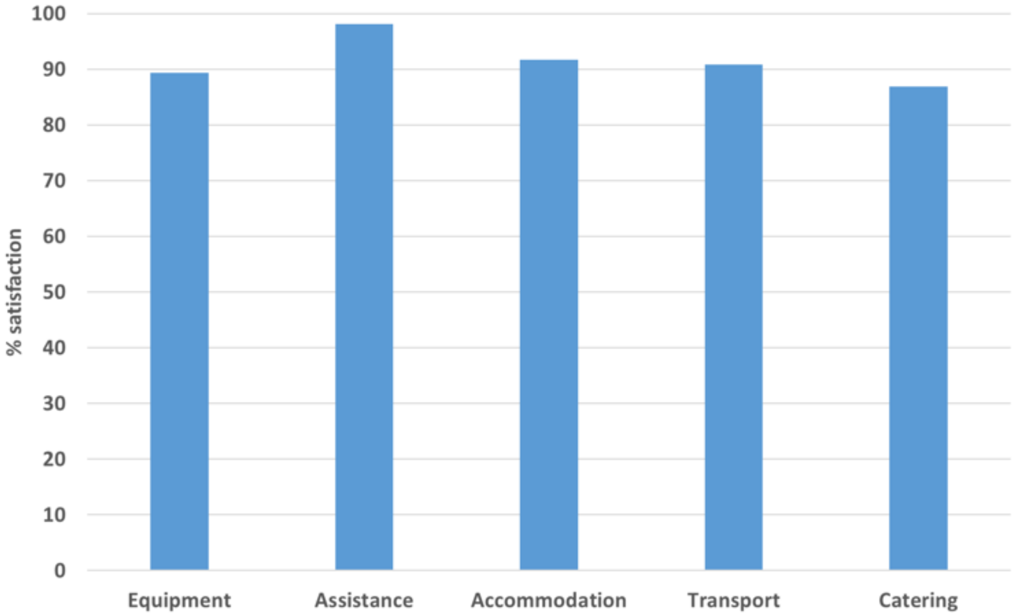
Figure 4: Average user satisfaction



Target Fabrication Operational Statistics 2022/23

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Introduction

This operational statistics report documents the total target delivery of the Target Fabrication Group of the Central Laser Facility over the 2022/23 operating period. The Target Fabrication Group is responsible for the supply of laser targets alongside a multitude of diagnostic elements, optical coatings and characterisation services (which are not covered in the scope of this report) for experimental campaigns across four high power laser (HPL) experimental areas at the CLF – two of which are driven by the Vulcan laser (TAP and TAW) and two by the Gemini laser (TA2 and TA3).

The Group provided targets for 10 HPL experimental campaigns at the CLF during the 2022/23 operating period, each of which typically lasted six weeks, as well as providing targets for external access experiments during the year.

A solid target comprises virtually any material (metals, polymers and ceramics), coated to nanometrically precise thicknesses in a range of geometries and characterised to ensure they fall within tight tolerances. There is generally a difference between the type of target requested for Vulcan and those for Gemini experiments. Vulcan targets are typically more complex (for example single target assemblies on posts) with a focus on precision-assembly 3D microstructures and mass-limited targets. Gemini targets are typically less complex and more mass-manufacturable to accommodate the higher repetition rate (HRR) of the laser. Typically targets include multi-layer or ultra-thin foils on arrays or tape substrates.

Supported Experiments

Over the 10 experiments that the Target Fabrication Group delivered for in the 2022/23 operating period, seven campaigns took place on Vulcan and three on Gemini. Table 1 shows the breakdown of the experiments which were supported. Not captured within the scope of this report are TA2 campaigns for which targets were usually externally provided.

Table 1: Experimental campaigns supported by the Target Fabrication Group over the 2022/23 operating period

Experiment	Area
0822 McKenna	Gemini TA3
1022 Borghesi	Gemini TA3
0323 Hooker	Gemini TA3
0422 Fuchs	Vulcan TAW
0922 Gizzi	Vulcan TAW
1122 Palmer	Vulcan TAP
0123 Carroll	Vulcan TAP
0123 McKenna	Vulcan TAW
0323 Borghesi	Vulcan TAP
0323 Armstrong	Vulcan TAW

The previous operating period (2021/22) saw a large number of simple tape-driven targets (off-the-shelf spools of material with no coating or assembly required) which were shot on TA2 and thus it was deemed necessary for future statistical reports to separate the target issue list between simple tape targets and targets which require significant fabrication effort.

Target Complexity and Classification

The variety of target types provided by the Target Fabrication Group are categorised as Class 1, 2 and 3 targets which provides a method of classifying the complexity and research/planning necessary for experimental delivery. The definitions are somewhat subjective in nature, but are typically classified as follows:

- Class 1: Targets that require fewer specialist resources to manufacture. Materials are typically procured 'off-the-shelf' and minimal specialist equipment is required for assembly. Typical targets include several-micron-thick foils or alignment wires glued to posts.
- Class 2: Targets that require the use of specialist manufacturing equipment and knowledge, which would be a very involved process for a non-Target Fabrication specialist to replicate. Examples include multi-nanometre thin-films and multilayer coatings.
- Class 3: Targets that require long-term R&D projects to establish and perfect, often referred to as "high-specification targets". Such targets include complex 3D assemblies, MEMS-components, low-density foams and multi-step tape targets.

As previously mentioned, a target can take many different forms – a single foil on a post or a large area of foil mounted on an array with many apertures (comprising many targets on one frame). It is, therefore, important to make the distinction between a component and a target. In the case above, a post or frame is considered a single component, and each shootable area on a component is considered a target.

Target Supply

For the 10 supported experiments, the Target Fabrication Group delivered a total of **1573 targets** over the 2022/23 operating period. Including tape targets, the total number of supplied targets was **5073**.

Of the 1573 targets delivered, 32.3% were manufactured for Gemini experiments and the remaining 67.7% for Vulcan experiments. Including tape targets, the percentages are 79% and 21% for Gemini and Vulcan, respectively.

Referring to the target classifications above, Figure 1 shows the breakdown of target complexity for both Vulcan and Gemini (excluding TA2) experiments over the 2022/23 operating period.

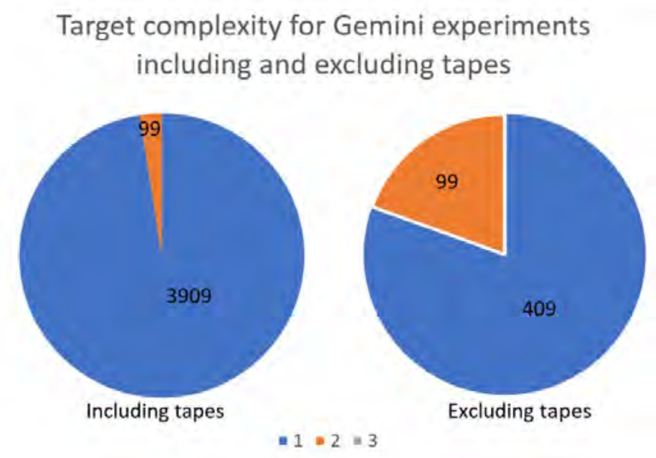

Figure 1: Target complexity breakdown for Gemini experiments over the 2022/23 operating period

As none of the targets requested for Vulcan experiments comprised tape targets, Figure 2 shows a single graph documenting the breakdown of target complexity.

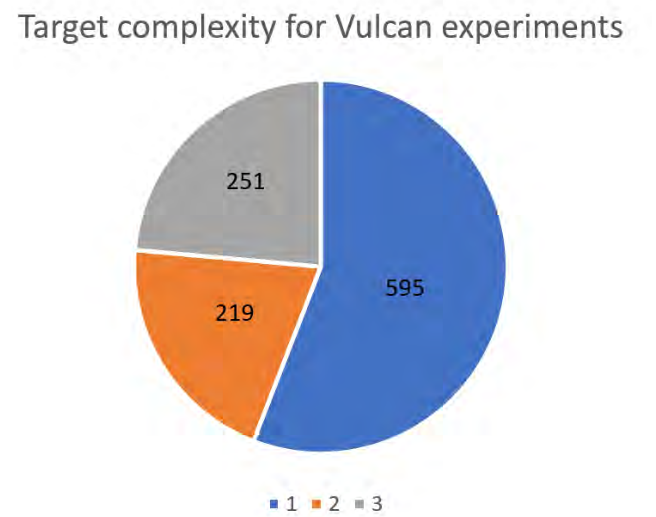

Figure 2: Target complexity breakdown for Vulcan experiments over the 2022/23 operating period

Figures 1 and 2 illustrate the difference in general target complexity requested between Gemini and Vulcan experiments.

Excluding tape, 80% of Gemini targets fall into Class 1 – primarily thick foils and alignment targets. The remaining 20% Class 2 targets are all ultra-thin foil targets.

The majority of Class 1 Vulcan targets were thick foils (44%); however, there were a considerable number of Class 3 targets (251 in total) over the period. These all comprised 3D micro-structures, which ranged from precision-machined assemblies with multiple foils per component to multi-faceted gas cells.

Target Supply Trends

The Target Fabrication Group keeps a record of all targets that have been issued to each experiment in the CLF for referencing and QA purposes, and as such is wishing to reinstate the ISO9001 quality management system, which will be especially important when shot numbers inevitably increase in the coming years.

Following the commissioning of the EPAC Facility, it is expected there will be a considerable increase in the number of tape targets required and the Target Fabrication Group is developing a tape etching and coating capability to deliver for this increase in demand. A liquid targetry system is also in development, producing rapidly replenishable and debris-free targets that will be crucial for high-repetition rate (1 Hz+) experiments.

It can be seen from Figure 3 that, if simple tape targets are excluded from the statistics, the supply of complex targets across the CLF has been relatively stable over the last decade, with an average number of 2228 targets provided per year. However, because Target Fabrication has been offering the capability of a tape-driven targetry solution to users over recent years, actual shot numbers on targets have increased substantially. This operating period saw 3500 targets shot on simple tapes – as TA2 data was not captured in this report this number is likely to be far higher. Last year, for example, saw 79000 simple tape targets shot on TA2.

Figure 3 also shows the percentage of targets requested that were not on the target list initially, and were requested by user groups in the planning phase of the experiments. Due to the complexity of target manufacture, targets are often manufactured many weeks ahead of each experiment.

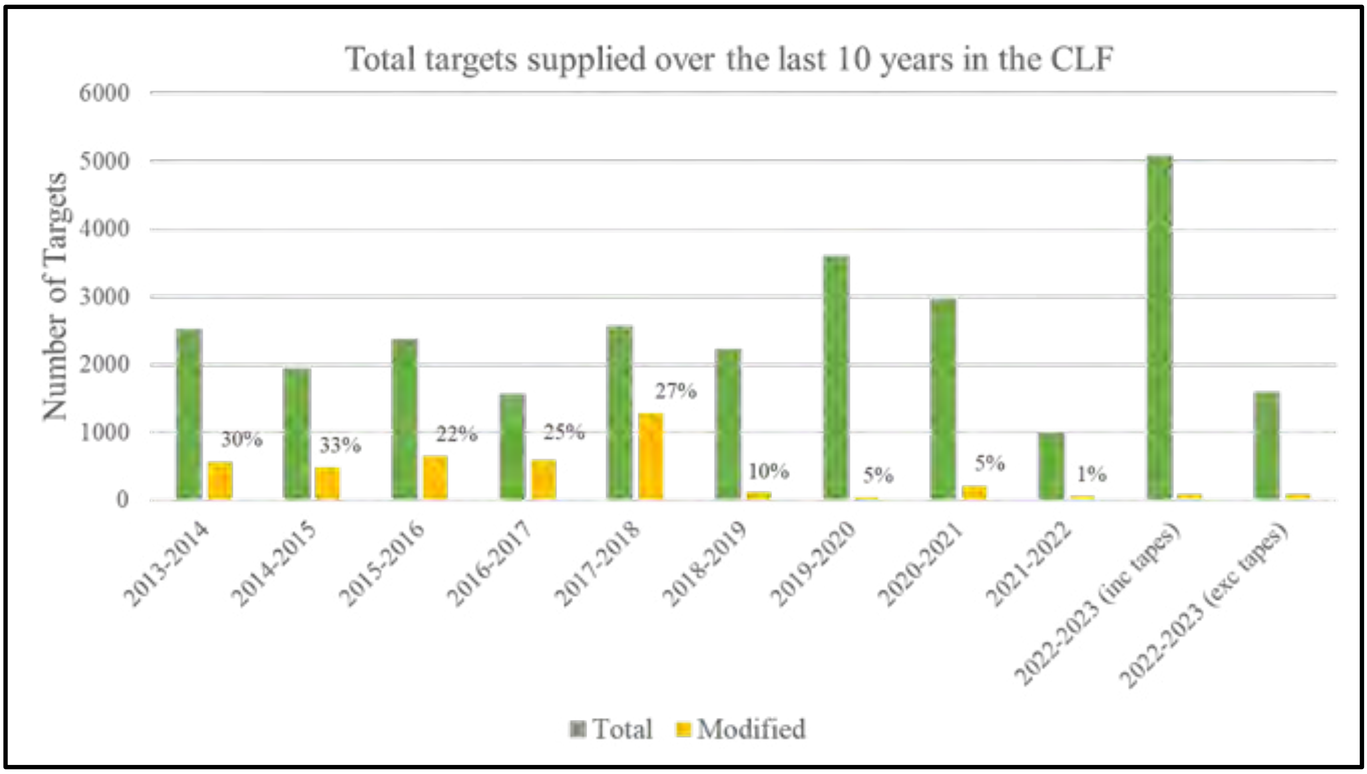

Figure 3: Target supply across the CLF over the past decade, including (green) and excluding (yellow) tape targets for the 2022/23 period

The benefit of having an embedded Target Fabrication Laboratory within the CLF is that that the Group can quickly adapt to a change in demand, and should the user groups request a last-minute change of target – within reason – it can be accommodated. Change requests are often due to an experimental objective being re-appraised during a campaign, typically because on-shot data did not agree with the data from the simulations and consequently target requests were adjusted during an experiment to better understand the physical conditions of interest. Such flexibility can often make the difference between a successful and an unsuccessful campaign and is of great benefit to users at the CLF. In total over the 2022/23 operating period, 87 of the 1573 targets (6%) supplied were modified.

Figure 4 displays the number of targets that were returned due to being out of specification. As can be seen, there has been a significant reduction over recent years in the number of returned targets, with a total of 51 targets returned over the 2022/23 period compared to 476 in the 2013/14 period, for example. The reduction suggests an improvement in general target quality, which can be attributed to better characterisation tools and more rigorous quality standards and verification practices. However, non-return of non-conforming targets without notification needs also to be considered when interpreting the target numbers.

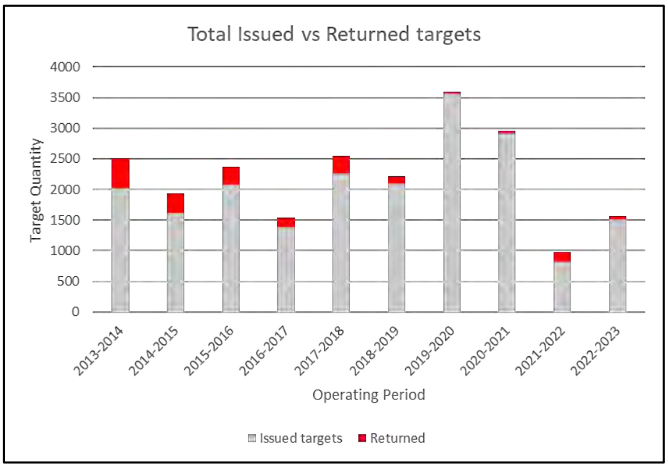

Figure 4: Returned targets vs total issued targets over the last decade

Future Targetry Supply

With the planned shutdown of the Vulcan facility in September 2023 (although the Target Fabrication Group will provide targets for CLF experiments conducted on other HPL facilities), it is anticipated that the number of higher classification targets might decrease compared to the last few years.

In anticipation of EPAC coming online in 2025, the Target Fabrication Group has developed a tape drive targetry solution for the supply of targets in vacuo and is integrating a range of technologies to be able to manufacture targets on tape substrates with custom materials, geometries and thicknesses. This is a novel capability and will allow production of thousands of targets onto a single spool of material, fed into the interaction point of the target area to a z accuracy of ±2µm. [1-3]

A liquid targetry system is also in development that can produce nanometre-range sheets of liquid (such as de-ionised water) using a high pressure liquid chromatography pump and precision-machined nozzle assemblies. The system is expected to be able to provide a targetry solution for HRR systems such as EPAC, with the intention of also modifying the technology for use as a rapidly-refreshing plasma mirror. The reader is recommended to refer to the 2022/23 annual report article by D. Crestani for further information. [4]

External Contracts

In the reporting period 2022/23, the operations of Scitech Precision Limited (SPL), Target Fabrication Group's commercial spin out, supported the user community on external facilities and continued to expand with the ability to access MEMS technology and advanced laser machining being key revenue generators. The expansion of the user community across Europe and in the US drove sales of targets to a wider array of customers. A total of 36 (up from 32 in 2021/22) institutions engaged with SPL over this period for 115 individual contracts (up from 98) to a record value of £302k, which is a significant increase in turnover from the previous years and is in part due to the licensing agreement SPL has with STFC to market and sell the tape drive technology. In the reporting period, SPL continued to upgrade its capabilities in additive manufacturing and also further developed capabilities to deliver high repetition rate targets by integrating CLF tape systems with its Excimer laser tool.

Summary

Over the 2022/23 reporting period, the Target Fabrication group has delivered a total of 1573 laser targets over 10 HPL experiments that took place in the CLF. Excluding tape-driven targets, 67.7% of the targets were provided to the Vulcan target areas (TAP and TAW) and the remaining 32.3% were delivered to the Gemini TA3 target area. If tape-driven targets are taken into account, the respective breakdown is 21% and 79%.

The complexity of requested targets (Class 1, 2 and 3) was 55%, 21% and 24%, respectively, for Vulcan experiments and 80%, 20% and 0% for Gemini experiments.

Data has not been included for Gemini TA2 experiments, however, which accounted for by far the largest proportion of targets in the previous operating period.

It is anticipated that future target demands will move more towards complex tape driven targets and that, due to the shutdown of Vulcan in 2023, there will be a (short-term) reduction in the number of complex 3D micro-assembly targets.

References

[1] *S. Astbury, W. Robins, C. Spindloe & M. Tolley, "Progression of a tape-drive targetry solution for high rep-rate HPL experiments within the CLF", CLF Annual Report 2018-2019*

[2] *W. Robins, S. Astbury, C. Spindloe & M. Tolley, "Experimental Testing and Fielding of the CLF Precision Tape Drive in the Gemini Target Area", CLF Annual Report 2020-2021*

[3] *W. Robins, S. Astbury, C. Spindloe & M. Tolley "Advances in Tape Target Technologies towards 1Hz Operation for EPAC and other High Repetition Rate Facilities", CLF Annual Report 2021/22*

[4] *D. Crestani, S. Astbury, H. Edwards, W. Robins, C. Spindloe & M. Tolley "Liquid Targetry Development for High repetition rate experiments", CLF Annual Report 2022-2023*

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