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Chapter 6: The building of the Book Storage Facility

1 Introduction and strategic need

To deliver the programme for improving and rationalizing our library estate the Bodleian Libraries first required a high-capacity off-site Book Storage Facility (BSF). We needed sufficient capacity to accommodate new growth in the collections, lower-use stock from libraries being merged or re-purposed, and large-scale collections from buildings being emptied for refurbishment, in particular the New Bodleian Library. In order to provide optimal conditions for the storage of documents the BSF would need to comply with British Standard BS5454, especially with regard to fire.[1] It would need to meet the Libraries' storage requirement for a 20-year period and be high-density and so cost-effective to build and operate. It would have to be sited in an industrial area, given its bulk and height, and yet it would need to be close enough to libraries to allow for the rapid delivery of requested books. These requirements were met through the construction of the University's largest ever book repository at South Marston on the east side of Swindon, some 45 kilometres (28 miles) from central Oxford. After an extended planning period during which we overcame a number of challenges, construction of the £24 million Book Storage Facility began in September 2009. (Figure 6.1) The completed BSF opened in September 2010 with a capacity of 247 linear kilometres of shelving and over one million maps.

2 Background

Oxford University's centrally funded libraries first began to make use of offsite storage in 1975, when the then Libraries Board opened the first of a series of low-cost book storage modules at Nuneham Courtenay, 13 kilometres (8 miles) outside Oxford. By 2003, seven modules had been constructed in all, to a stan-

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1 *BS5454:2000 Recommendations for the storage and exhibition of archival documents* (London: BSI, 2000).

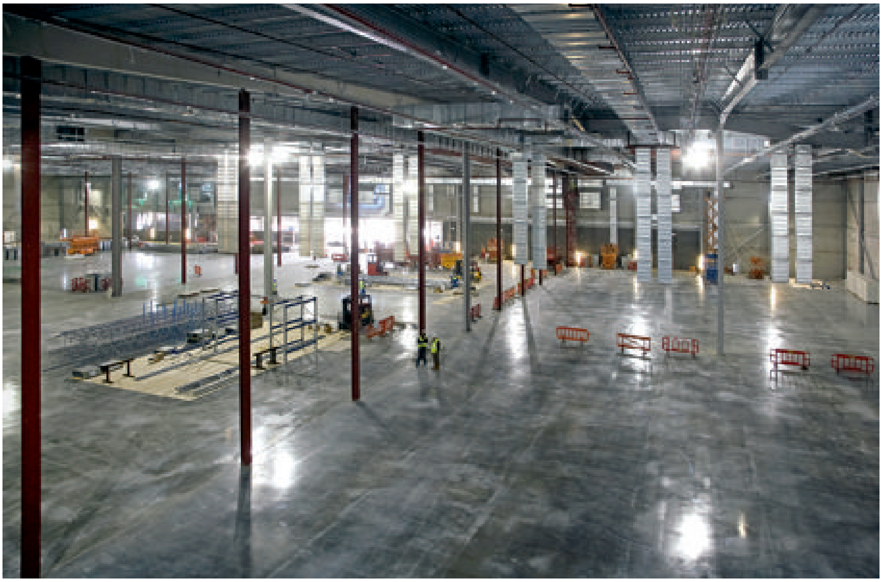

Figure 6.1: The Book Storage Facility under construction

dard pattern. Each module comprised a single-storey 500 m^2 room containing four blocks of conventional mobile shelving or planchests (for maps), arranged around two gangways. On average a module provided some 5,500 m of storage and the whole 3,477 m^2, development provided storage for 37,423 m or 1,272,000 nominal volumes. An ancillary wing provided facilities for staff and a small room to serve as a reading room for occasional use by visiting readers. Although some air handling was provided, the development did not comply with the relevant standards for library storage and particularly lacked adequate fire engineering systems.

The slow development of the Nuneham Courtenay Book Repository, over nearly thirty years, and the limited size of its component modules, meant that it was unable to provide a strategic solution to Oxford's remote storage needs. A notable feature of the repository was its location within an eighteenth-century walled kitchen garden and, from the outset, planning permission was severely limited. Although the University brought forward plans in 2002 to more than double the size of the facility to some 65 linear kilometres, its planning application was refused and the University had to look elsewhere to meet its strategic needs.

Faced with a significant lead time to develop plans for a new, larger store, libraries were forced to begin making use of commercial off-site stores. By the time of the BSF's opening, some 2,000,000 books had been placed into commercial storage with the companies Iron Mountain and DeepStore. The high costs of contracting out storage meant that this could not in itself provide a sustainable strategic solution.

3 Towards a high-density storage solution

The move away from the Nuneham Courtenay Book Repository and its limitations brought an opportunity to make use of higher-density storage methods that, per book stored, would reduce both the capital cost of construction and annual running costs. In 2000 the University had acquired warehouse units on the Osney Mead Industrial Estate 1.3 kilometres (0.8 miles) and just under 4 kilometres (2.5 miles) by road from the central Bodleian. Although these buildings were themselves old and of poor quality, their sites, covering approximately 1.5 hectares (3.75 acres), had considerable potential. Transfer times between Osney Mead and the central Bodleian were about 20 minutes, allowing requested items to be rapidly delivered from storage to reading rooms. There were precedents for large-scale industrial storage developments on the estate, including tall structures. Moreover, the sites were immediately adjacent to a library support services building, the Osney One Building, which was to be refurbished as accommodation for the Libraries' departments of Conservation & Collection Care and Technical Services.

In March 2004 a group of Libraries staff undertook a study tour of high-density storage systems on the west coast of the United States. The group saw three different storage solutions. High-level static, narrow-aisle shelving with access floors was seen at the University of California's Northern Regional Library Facility (NRLF) at Richmond, California. A 'Harvard Model' fixed rack with access by High-Level Order-Picker was viewed at Stanford University's SAL3 facility at Livermore, California, and Automated Storage and Retrieval Systems (ASRS) were seen at Sonoma State University Library at Sonoma, California and the Lied Library at the University of Nevada, Las Vegas. Within the UK, the group visited a number of retail distribution centres using similar technology, and made initial enquiries with the leading providers of logistics systems. Further reference-site visits were made to the US and to the National Library of Norway's Book Repository at Mo i Rana in 2005.

We carried out a number of internal option appraisals in 2004 and 2005, exploring potential layouts on the Osney site and comparing a range of building types and storage solutions. We recognized that a specialist logistics consultant would be needed to undertake a thorough assessment of options and in February 2005 Total Logistics Ltd were appointed. Their initial study compared four options (Harvard Model, ASRS, conventional mobile shelving in a multi-storey building, and NRLF-type high-bay shelving). Their report recommended ASRS as the lowest cost option in terms of recurrent costs per book.

4 An Automated Storage and Retrieval System

Detailed plans were drawn up for an ASRS facility at Osney. This comprised a fourteen-aisle configuration of high-bay racking, with each aisle served by a fully automated crane controlled by a warehouse management system communicating directly with the library management system. One of the fourteen aisles was to hold 620 map planchests with the remaining thirteen housing books stored in large polypropylene trays. The book aisles were served by a cross-link conveyor moving trays between storage racks and operator positions, where individual books could be picked or re-filed. The facility would be fully compliant with BS5454: 2000 and would be protected by a low-oxygen environment to prevent any fire ignition.

The site stood partly on the flood plain of the River Thames, at or below the 1-in-100-year flood contour. As a result, the design incorporated a defensive bund wall to protect the building against a 1-in-5,000-year flood, and sub-floor voids to hold flood water and prevent consequential flooding of neighbouring property.

The proximity of the site to the city centre meant that the impact on the famous skyline of 'dreaming spires' had to be minimized. Our attempts to meet the City Council's objections led to a highly unusual design for an ASRS. The overall height of the building was limited to 18.2m and a wave-form, or 'sinusoidal', roof was adopted to soften the building's profile. Varied materials and finishes were carefully chosen to break up the mass of the building and help to blend it into its surroundings. The novel roof line meant that height of the rack and cranes inside the high bay had to vary between 7 m and 15 m.

The University submitted a planning application in February 2007 and it was passed by the city's Area and Strategic Planning committees. However, such were the sensitivities around visual impact and flooding that the application was subsequently reviewed in a full meeting of the City Council in November 2007, and rejected.An appeal lodged by the University also failed and it became clear that a new site had to be found.

5 A new site and a new approach

After a detailed search of more than 90 sites across the region a highly suitable site was identified at South Marston, on the eastern edge of Swindon. Some 45 kilometres (28 miles) south-west of Oxford, the location allowed a transit time of only 45 minutes. The site was well elevated and, being adjacent to other high-bay industrial units, had no onerous planning restrictions.

The hiatus resulting from the change in site allowed us to review the Libraries' strategy and the storage solution itself. The Osney Mead site had been close enough to city centre libraries to house material regardless of how heavily it was used, since a fast and frequent delivery of material to reading rooms would have been possible. A more remote site would not allow such rapid access and a different strategic approach was called for. The proposals described in other chapters of this book enabled the remote store at Swindon to hold lower-use material. Accordingly, the case for a rapid, automated retrieval system was reduced and a review of storage solutions showed that a Harvard Model facility would be more suitable. In particular, we felt that a more staff-based (though still mechanized) solution would be more flexible, with scope to reduce operating costs should the demand for physical books decline with increasing digital access. Ultimately a Harvard Model repository could be served by a very small staff, while an ASRS repository would require ongoing support for a large fleet of automated cranes.

We undertook a further study tour to the USA in May 2008, focusing on the 'high-density' repositories at Harvard, Yale and ReCAP. All of these Harvard Model facilities use the same storage approach. Each item is given an individual barcode recorded in simple warehouse inventory software which communicates with the libraries' management systems. Items are placed in barcoded cardboard trays which are held, several deep, on barcoded steel shelves in banks of high-bay racking separated by narrow aisles. The inventory system records the tray, shelf and aisle location for every item in the store and tracks the picking and re-filing of individual documents as they are withdrawn for reader use and returned. Staff access the high-bay racking from onboard electric High-Level Order-Picker vehicles, riding on access platforms that lift them and their picking trolleys high into the air. In the UK the system is known as Very Narrow Aisle storage. The use of this industrial logistics approach for library storage was pioneered in the US by the late Reese Dill and there are now over sixty high-density storage modules across the USA. Although it is widely used in commercial logistics it had never been applied to library storage in the UK. The Libraries were able to benefit from Reese Dill's tremendous experience through his consultancy services, though a number of deviations from his established model were required because of differences between US and European regulations, products and suppliers and the specific nature of the Bodleian's project.

6 Designing the South Marston Book Storage Facility

The building housing the storage facility was designed closely around the operations that were to take place there, and in particular around the immense shelving system used to hold the stock. (Figure 6.2) The shelving in turn was designed closely around the collections that it would hold, and the requirements of the staff and mechanical handling equipment used to access it. Accordingly a great deal of early work was done to understand more fully the size, nature and usage of the Libraries' collections. A planning base was drawn up to record the quantities of manuscripts, printed books, microfilm, maps and other material identified for transfer to the BSF on completion. We analysed the dimensions of library material, in the various size groupings that have been in use in varying periods of the Libraries' 400-year history. A range of sample material was weighed to determine both the load that the shelving system would have to carry and the maximum weight of items that staff would need to lift. We analysed reader requests to estimate the overall number of requests that the BSF would have to handle as well as the day-to-day and hour-to-hour patterns of usage. This preparatory scoping work showed that the BSF would need a capacity of some 8.4 million nominal volumes and 1.2 million maps. It would need to accommodate objects up to 20 kg in weight and some 550 mm x 1,000 mm in size. The initial estimate of overall demand for items was that this would be approximately 230,000 each year, with a peak requirement for 1,595 retrievals a day.

To achieve a good balance between high-density storage and efficiency of operations the design of the shelving system needed to take a number of considerations into account. To maximize storage density, the blocks of shelving would need to be as tall and long as possible, with access aisles as narrow as possible and shelving as deep and as closely spaced as possible. (Figure 6.3) At the same time, staff would have to be able to access all material quickly and safely, with minimal manual handling. The height of the shelving installation, and of the building overall, was governed by planning restrictions. Allowing for a roof structure and service zone above the shelving resulted in a shelving height of 11.4 m. The High-Level Order-Pickers required to reach the top of this racking required an aisle width of just 1.5 m. Increasing the height to beyond 11.4 m (had the site allowed this) would have required larger, wider vehicles with correspondingly wider aisles and this would have significantly reduced density. The length of the shelving blocks was determined in part by the size and layout of the site itself and partly by the need for staff to be able to travel to all areas of the shelving relatively quickly –excessively long blocks would increase travel time to the shelves.

Figure 6.2: The Book Storage Facility from the south

Figure 6.3: A narrow aisle

A block length of 71 m would allow efficient storage and access, and would result in a building size that was acceptable from a planning perspective and which would allow for the further development of the site in the future. The depth of the shelving units was determined by the limits of human reach. Staff had to be able to withdraw all items from the shelf from a safe standing position without the need to lean out into the shelving. The length of the shelves was determined by structural considerations. Although the use of wider shelves would improve density horizontally by reducing the number of support uprights, this gain would be lost through a corresponding reduction in density vertically because, to maintain strength, wider shelves would also need to be thicker. A cost-benefit analysis was undertaken to determine whether we should use specially designed shelves sized to our own requirements, or use existing commercially available shelf sizes. We found that adopting existing shelf sizes would be the most cost-effective approach, with minimal impact on density. The optimal dimensions for a standard shelf were found to be 1,283 mm wide x 990 mm deep.

The vertical spacing, or pitch, of the shelving was a crucial factor in achieving high density. For structural and health and safety reasons shelf installation and alterations could only be done by the shelving contractor. As a result, we had to determine all shelf pitches in advance. We would require a number of standard pitch settings, enough to accommodate the range of stock heights without incorporating too much free space. We gave careful consideration to the size groupings occurring within the collections. In doing this the Bodleian departed from the usual practice followed at American Harvard Model depositories, where on arrival all incoming material is split up and sorted into new depository-specific height bands according to sizing templates. This practice has largely been necessary because of the amount of stock coming from libraries holding unsized material in Library of Congress classifications. The Bodleian, from which the vast majority of the BSF holdings would come, had already been sorting and storing stock by size in a number of different schemes from the seventeenth century onwards. The BSF could take advantage of these existing size bands. Being able to ingest existing stock into the BSF without sorting by size would also allow a rapid initial load of the facility, so reducing unit costs, allowing savings in commercial storage and allowing the New Bodleian to be vacated promptly ahead of refurbishment. Initially, eight BSF shelf pitches were proposed, but this was reduced to six by combining two of the size bands with adjacent size bands.

The storage trays form a key component in the overall storage solution. The requirement was for these to be of sufficient quality to withstand physical handling and protect their contents for a design life of 50 years, all at a relatively low unit cost, given the large numbers required. The overall concept was based on that used in the United States but dimensions and the form of construction

Figure 6.4: Storage tray

were altered for the BSF. Archival-quality corrugated board was used because of its rigidity and light weight, allowing a high-throughput, automated production process and therefore lower costs. Archival corrugated board has not been used much within the UK and a special make was produced for the BSF by Smurfit Kappa in Norwich from Billerude White paper imported from Germany. Flat tray matrices were die-cut by Caps Cases Ltd of Newmarket and delivered on pallets to the BSF, to be made up on site as needed. Nylon grab-handles and backing plates were provided by Item Products Ltd. During fire tests at the Building Research Establishment the original polypropylene handles were found to present a fire risk and fire-resistant nylon was substituted. Five different tray sizes were produced, with the largest in two variant forms to accommodate books and two-part flat archival boxes. At the prototyping stage, sample trays were tested under load to simulate 50 years of usage. The largest items, above 408 mm in height, would be stored laid horizontally, directly on the shelves, not in trays. Two different tray lengths were adopted. Trays A-B measure 488 mm in length and are stored two deep on the 990 mm-deep shelving. Trays C, D, E and XE are for larger items. In order to reduce tray weight they are shorter, at 323 mm, and are stored three deep on the shelves. Trays are arranged in up to seven ‘files’ across the front of a shelf.

Figure 6.5: Planchests

Not all the material stored in the BSF is stored within this tray-based shelving system. One storage aisle has been built to a different configuration – a five-level multi-tier comprising standard beam pallet racking with in-fill access floors reached by stairs and served with a goods-only hoist. Four of the five levels hold some 600 map planchests with deep shelving above and the fifth is fitted out entirely with deep shelving for rolled maps and other items not suitable for the tray-based system.

Trays are loaded onto the shelving and individual items picked and later re-filed by staff on High-Level Order-Pickers. Selecting and modifying these was an important part of the design process since they interacted closely with the shelving and had to provide a safe working environment for operators. The order-picker selected was the Jungheinrich EKS 312, in a configuration where the operator faces forwards over the engine compartment to drive the order picker along the aisles, into position at a shelf, and then turns around to work from a trolley

Figure 6.6: High-Level Order-Picker

carried on forks at the rear of the vehicle. The order-picker has a triplex mast extending to a maximum pick-height (the height of the highest tray handle) of 10.6 m. Items stored on the lowest four shelves cannot be retrieved from onboard an order picker and staff dismount to access them. Two variant forms of the EKS 312 are used. The ZG model is used for loading the shelving and has a pair of moveable forks on the front, allowing heavy trolleys of filled storage trays to be raised and lowered to a comfortable working height. The LG model order-picker is used for picking and re-filing individual books and has non-moving forks that hold lighter book trolleys in a fixed position. Although manually driven by staff, the electrically operated order-pickers are steered by a wire guidance system embedded in the concrete floor while they are in the shelving aisles – any slight deviation from the centre line of an aisle is immediately compensated for. Separate transponders in the floor limit the speed of the order-pickers as they approach the ends of an aisle.

Two designs of steel trolley were specially made for the BSF. The heavier tray-to-shelf (TTS) trolleys have three shelves carrying up to 36 fully loaded trays or 1,224 nominal volumes. The top two shelves fold back when empty, to give access to the shelf below. In operation, the order picker operator brings a shelf of the TTS trolley up level with an empty storage shelf and filled trays are pushed out over the intervening gap into their final storage location. The lighter picking trolley has two fixed shelves below a fixed work surface at chest height. In use, this work surface is brought level with a storage shelf of book trays; the required tray, and any tray in front of it, is pulled out onto the trolley work surface and the requested book selected. The tray and its remaining contents are then pushed back into position on the storage shelving. This handling of trays on the trolleys and at the shelf is the principal manual handling activity in the BSF and the process and equipment were designed with the close involvement of health and safety consultants and University Safety Office staff. At no point in the BSF process do staff have to lift a loaded tray.

Material received by the BSF for ingest into storage, and the items being picked and refilled, are all processed in an ancillary hall next to the high-density storage area. This is an open-plan area that can be fitted out and re-configured for a variety of functions, from large-scale ingest projects and normal day-to-day book delivery operations to scanning and box-making. The benching and equipment in use here is therefore designed to be movable. Power and data are delivered from the ceiling as well as from the perimeter. The ancillary hall was sized to accommodate normal operations rather than the large-scale ingest operations that were needed in the first eighteen months of the building's life. Initially, we thought that we would need a temporary extension for this initial ingest project. However, through careful design, an efficient, linear arrangement of processing benches, the rapid processing of inbound stock at up to six benches and the temporary use of the high-bay for the storage of tray flats, the ancillary hall functioned efficiently without additional space. Ingest benches were designed to minimize manual handling. Hydraulic lift platforms were used to raise incoming transport totes of books to a comfortable working height, bench tops were equipped with roller-ball tops to allow trays to be pushed and pulled along through the process, computer screens, keyboards and barcode scanners were mounted over the benches on adjustable arms and electric stacker trucks were used to lift the heavy tray-to-shelf trolleys to bench-top height and to move them in and out of the high-bay area.

7 A building to house BSF operations

The building that houses this ‘storage solution’ comprises two distinct parts. The high-bay store houses the 31 aisles of tray storage and the map multi-tier aisle. In order to reduce risk it is sub-divided into four four-hour fire compartments, each with a capacity of some two million volumes. In day-to-day use, the compartments operate as one space linked by cross-aisles at the front and back of the high-bay. In the event of a fire, however, the connecting doorways close with automatic fire shutters to create four separate protected chambers. The high-bay is protected with an ‘in-rack’ water sprinkler system. Four levels of distribution pipework and a close arrangement of sprinkler heads ensure adequate protection. The system is pre-charged with water and in fire conditions the sprinkler heads activate automatically as the air temperature reaches 68°C (152°F). Because no UK or European standards exist for the installation of sprinkler systems in high-bay shelving (as opposed to racking), we had to conduct full-scale burn tests at the Building Research Establishment. These were highly successful, demonstrating that the sprinkler system design could effectively contain a fire for 90 minutes. Other fire-engineering systems incorporated within the design include air-sampling early fire detection, smoke curtains, smoke extract and, around the external perimeter of the building, an access roadway for fire tenders.

The high-bay walls are made of pre-cast, high-thermal mass insulated concrete panels carried on a steel frame and sealed with gaskets. The roof is of a heavily insulated, pitched construction with a single-membrane roof covering. The overall level of insulation and air-tightness is high, resulting in a highly stable internal environment with little or no variation in conditions from day to day. The environment is maintained with separate air-handling plant serving each of the four fire compartments. The concrete floor of the high-bay was cast ‘super-flat’ to ensure a smooth ride for order-pickers when travelling between the rack faces. It is cast with the minimal number of joints and these remained stable as the storage shelving was loaded with book stock.

Aisles are well lit, at high level, with luminaires controlled by movement sensors to ensure that stock is held in darkness for as long as possible. One of the fire compartments also houses the ‘pit-stop’ a bay for parking order-pickers and for dropping off and picking up trolleys. Adjacent to this is a battery charging room where batteries removed from the order pickers can be placed on charge. This room is separated from the high-bay storage area by a four-hour fire shutter.

Alongside this 9,561 m^2 high-bay lies the single-storey ancillary block, providing 1,425 m^2 of accommodation for operations, in the form of a reception area and security room, a sub-dividable meeting room, an office, common room, toilets, an IT hub room and a conservation quarantine room. The greater part of the ancillary

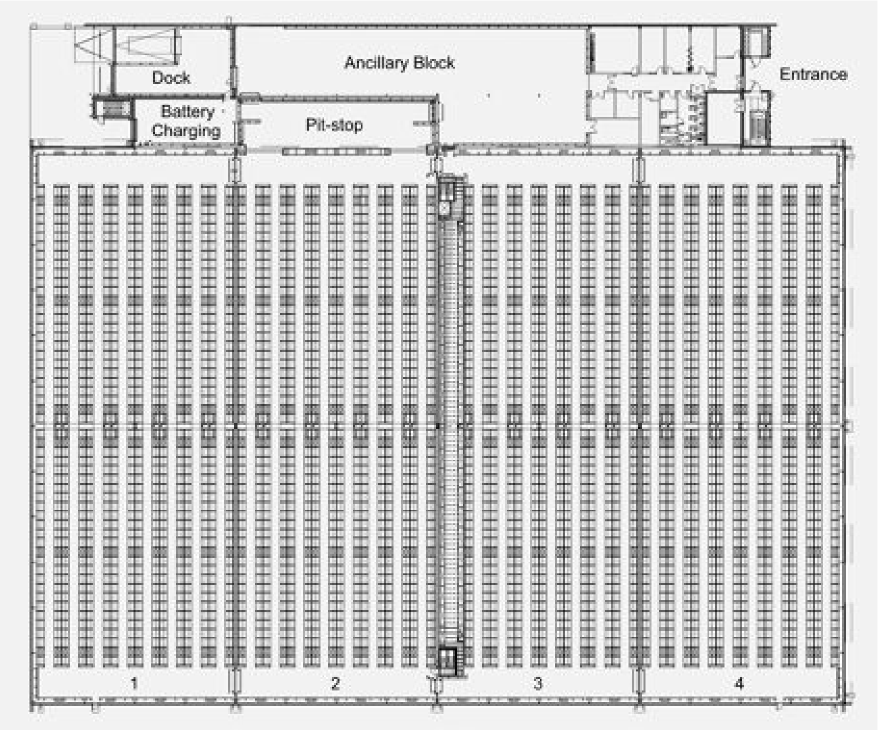

Figure 6.7: Book Storage Facility plan

block is comprised of the ancillary processing hall, an open-plan concrete-floored room of some 708 m^2. At the rear of the ancillary block is the loading bay with spaces for two 3.5-tonne box vans side by side, one with a 600 mm-high dock.

8 Specification

The Storage Facility is 45 kilometres (28 miles) by road from the New Bodleian Library.

- The building is compliant with BS 5454:2000
- Net area 10,986 m^2
- Net storage area 9,561 m^2
- Four separated four-hour rated fire compartments – sprinkler protection to BS EN 12845:2004

- Fully air-conditioned, temperature and humidity controlled environment. The design temperature is 18 °C ± 1 °C; the design humidity is 50 % RH ±5 %. Air Filtration to Class F7 of BS EN 770.
- 31 aisles totalling 3,224 bays with 97,132 shelf levels
- Total area of shelf surfaces 120,666 m^2
- Height of the shelving is 11.4 m, aisle length is 71 m
- When full the BSF will hold 745,000 trays for book storage
- BSF capacity is 247,000 linear metres (153.5 miles) of book stock equating to about 8.4 million volumes
- One of the four compartments contains a fire-separated Map Store with one Ground Floor and four Mezzanine Levels built to house 600 Map Cabinets holding over 1.2 million maps and large-format items
- 1,600 linear metres microfilm
- Maximum tray weight 19 kg
- Maximum shelf load 242 kg
- Maximum bay load – 6,118 kg (excluding weight of shelves)
- Map cabinet load 680 kg
- Five high-level order-pickers (VNA trucks) for use in regular operations
- Mechanical handling equipment: Jungheinrich UK
- Shelving: SSI Schaefer Ltd.
- BSF Information System: Generation Fifth Applications Inc.
- Main Contractor: Mace Ltd.
- Logistics Consultant: Total Logistics Ltd
- Architect: Scott Brownrigg

Notes

A linear metre (lm) contains 34 nominal volumes (based on ‘d’ sized books (9–12 inches in height) in the Bodleian’s Nicholson classification).
All floor areas are of Net Internal Floor Area (NIFA) in square metres.