ANATOMY OF THE SHIP

BATTLESHIPS *YAMATO* AND *MUSASHI*

Complete with more than **1020 scale drawings** and **350 colour 3D views**

Janusz Skulski and **Stefan Draminski**

BLOOMSBURY

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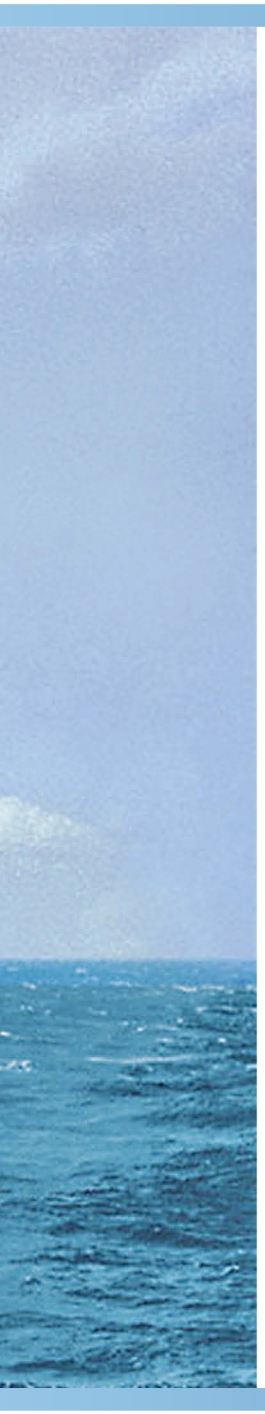

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Janusz Skulski
and Stefan Dramiński

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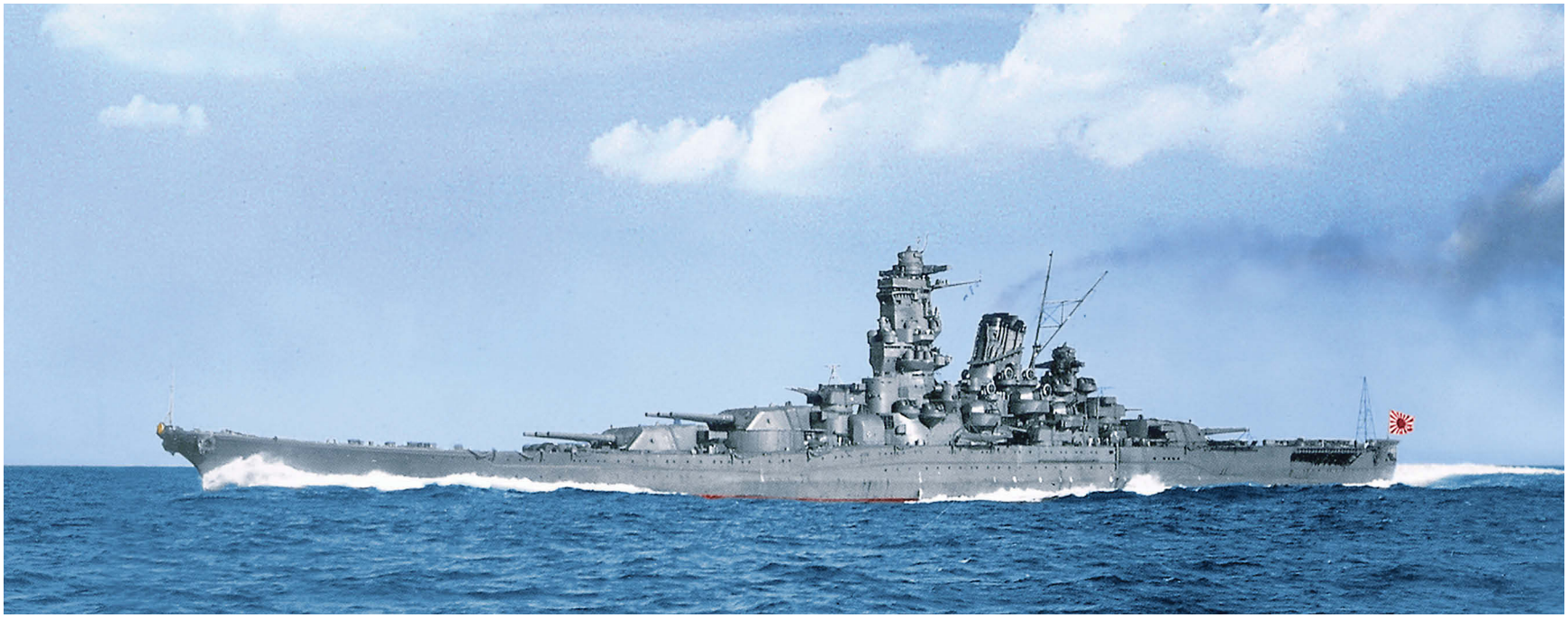
Janusz Skulski,
Krakow, May 2016

Port-side view of the Yamato *during trials in October 1941. This photo was found by chance three years after the end of the war and was the first portrait of the battleship published – up until then the only known photographs were US aerial pictures taken during the attack on the ship.*



INTRODUCTION

In 1988 Conway Maritime Press issued my first book on the Imperial Japanese Navy battleship, *Yamato*, the most powerful and most mysterious warship of the Second World War.

This new book is a significant update, based partly on drawings and partly on my own reconstructions from newly available sources – archival photographs and documentary drawings, all accessed with the invaluable help of my Japanese friends.

In researching the original edition I discovered many details about the ship that it was not possible to reconstruct at the time. But that book led me to new contacts in Japan, including an expert on the ships of the Imperial Japanese Navy. Thanks to him, I gained access to much new material that formed part of the navy yard documentation, including photographs and other documents.

Three expeditions were crucial in finding out more about the ships: the second expedition to the sunken *Yamato* made by the Japanese TV company, Asahi (the first, in 1985, was not fully successful), the expedition by the French ship *Ocean Voyager* in December 1999, and the sensational discovery of the remains of the *Musashi* by the Paul G. Allen expedition in March 2015 after eight years of research.

Since finishing the first book, I have continued my research and study of the *Yamato*, collecting much new material, making new drawings and building study models of the battleship fragments. After this, all done in consultation with Japanese experts, I started to make completely new views of these magnificent ships. It is now possible for the first time to show the beauty and terrible force of these strategic battleships of the Second World War and, as was the case the first time, to make real, not approximate, working plans.

Thanks to my friend Mr Stefan Dramiński, creator of the splendid 3D pictures that accompany the plan drawings, it is now possible to show more clearly the architecture of the ship and equipment.

Of course these splendid battleships will never be able to reveal all their secrets, mainly because a large part of the inner construction and technical achievements will be never be known. Staff of the Imperial Japanese Navy were ordered to destroy all drawings and photographs before the surrender, while the condition of both battleships at the bottom of the sea, as a result of huge explosions at the time of their sinking, is tragic.

And finally, some more interesting, though not official, information. In the years after I finished the first edition I was in contact with still-living members of the *Yamato* crew, from whom I remember two facts. First, during the *Yamato* full-power trials in October 1941 it was announced in an official statement to the crew that the ship had increased its speed to 30 knots. Second, in the middle of her last battle on 7 April 1945, it was announced that the ship had been hit by 16 torpedoes. Please look at the hit scheme on page 43.

YAMATO AND *MUSASHI* – SUPERBATTLESHIPS

Post-war Allied censorship probably diminished the achievements of the Japanese in the construction of their battleships. The ships, often named superbattleships or strategic battleships, were built mainly to oppose US battleships – with the capability to annihilate them in battle – but the US never in fact fought against them. *Yamato* and her sister ship *Musashi* were sunk by the planes of the US carrier forces. As a result of revolutionary changes in sea warfare tactics, these carrier planes had become the fleet's main force of attack, giving battleships in some measure an auxiliary function. When the Japanese Bureau of Naval Construction began to make plans for the new battleship in 1934, there was no forewarning of the near supremacy of naval air forces and so she more strongly reflected the Tsushima tradition and the sea battles of First World War.

These superbattleships, built by the supreme efforts of their constructors and the naval architects of the Imperial Japanese Navy, were extremely costly and, due to developments in research and new technology, were obsolete almost from the time they were accepted into service – seven years after the first design emerged.

On 16 December 1941, when *Yamato*, the first of four projected ships, entered service, the world's most powerful battleships were:

UK	*King George V* class	227.1 m long 38,000–44,460 tons displacement
USA	*North Carolina* class	222.1 m long 38,000–46,770 tons displacement
France	*Jean Bart*	247.8 m long 42,806–49,850 tons displacement
Italy	*Littorio* class	237.8 m long 41,377–45,963 tons displacement
Germany	*Bismarck* class	(252.0 m long 42,900–52,600 tons displacement).

(*Musashi* was completed on 5 August 1942; *Shinano* was converted into an aircraft carrier and completed on 19 November 1944; the fourth ship, No 111, was cancelled about a third of the way through its construction.)

Yamato exceeded those listed above not only by her 69,100–72,809 tons displacement and the calibre of her guns, but also by the shape and construction of her hull, her armour protection, her gunnery and her optics. By any standards she was a tremendous achievement for the Japanese naval engineers and architects.

Yamato's 46cm (18in) guns, with 42–44km range and superior optical equipment, were the largest and most modern naval guns ever mounted and far exceeded the quality and construction of those of other nations. Her 15.5m rangefinders gave tremendous precision to the main gunfire; her armour protection was a maximum 650mm thick and the side armour plate 410mm thick; and the shape of her hull reduced water resistance to a minimum. All in all, her construction was an extremely difficult and expensive enterprise, significantly outstripping the difficulties encountered building the typical dreadnought.

Yamato and her sister ships *Musashi* and *Shinano* were considered the strategic weapons of the Imperial Japanese Navy; their design and construction were top secret and carefully guarded against recognition.

Unfortunately, just before the Japanese surrender, when the three ships lay on the seabed, orders were given to destroy any documentation about them – including all the drawings and even photographs of the *Yamato*s – which had been deposited in the Japanese Naval Archives.

The special services carried out this task to the letter, so that for many years after the war, the only surviving records of the ships were the aerial photographs taken by US Navy aircraft during their attacks on the giant ships. It was not until 1948 that the first photograph of *Yamato*'s portside, discovered by chance, was published; the most recent was published in 1981. Only fragments of the original documentation have survived, and, became partly available to the public between 1995 and 2015.

It is likely that the explosions on both battleships were ignited partly by 15.5cm, 12.7cm and 25mm rounds, causing the explosion of the powder magazine, and partly by the shells of the 46cm guns when the ships rolled over. With the explosion of *Yamato*'s aft magazines it is possible that the fire that arose after the bomb struck the rear turret of the 15.5cm gun was not extinguished.

DESIGN

The 1922 Washington Treaty, with its prohibitions on the building of new battleships, brought a halt to the 8–8 Project for the development of the Japanese fleet, which comprised the building of eight modern battle cruisers and eight large modern battleships. This was quite a blow for the Japanese, particularly for their designers. Then came a change in the concept of

Starboard view of Yamato *from trials in October 1941*

warship construction. The designers and engineers wanted to increase the quality of the new units. They already considered the US Navy a potential opponent and wanted to ensure that their ships would be stronger and better armed than their US counterparts.

Despite treaty prohibitions, the Bureau of Naval Construction carried on with their studies and research and preparations for building the battleships reached a new phase of development at the beginning of 1930, although work was limited to preliminary studies until 1934. It was in October 1934 that the Bureau of Naval Construction received from the Naval General Staff the order to produce a design study of a new battleship with 46cm guns and a speed of 30 knots (US battleships then had a speed of 24–25 knots and maximum 40.6cm guns).

The first finalised design was completed on 19 March 1935 under the designation A-140. The planned ship was to be bigger than the actual *Yamato*: length 294m, beam 41m, 69,500 tons displacement, 200,000hp turbine engines, speed 31 knots. But this was too large for the Japanese strategists, who reduced the speed requirement to 27 knots.

It was a difficult decision because, until then, they had attached great importance to high speed. The Bureau of Naval Construction's three groups of outstanding naval designers – Fujimoto, Hiraga and Fukada – had drawn up as many as 23 preliminary designs up to March 1937. After 1 April 1935, when the penultimate design stage had been completed, the naval designers suggested a mixed propulsion system of diesel and turbine engines.

The turbines, with a total of 75,000hp, would drive two propellers; the diesel engines, with a total of 60,000hp, would drive two other propellers. After the second design stage it became the norm in all other versions to install diesel engines as the main machinery.

But, that time the Japanese Navy had a powerful two-cycle, double-acting diesel engine providing more than 10,000hp. These engines had been used successfully as the main propulsion for the submarine tenders *Taigei*, *Takasaki* and *Tsurugizaki* (all these three were converted into aircraft carriers) but at the time the Japanese did not possess any of the 30,000hp diesel engines that were to be used in *Yamato*.

For machinery of the same propulsive power, the diesel had the advantage of appreciably lower fuel consumption than the turbine by about 68 per cent, although the diesel was slightly heavier – about 1.07 per cent.

About two months after the provisional plans had been completed, in July 1936, the designers came across an unexpected difficulty, which caused drastic changes to be made.

Yamato's engine rooms were to be covered with 200mm thick armour-

Quarter view of Yamato *running builder's trials on 30 October 1941. The boat stowage hangar, catapult and lattice antenna mast on the crane platform are clearly visible.*

plating which was an integral element of the hull's armoured box. The plating was not only protective, but an integral part of the ship's structure, so after the diesel engines were installed it would have been impossible to replace them if they happened to cause problems. The designers had to return to their original plan and use 150,000shp turbine engines as the propulsion plant. In March 1937, the final design was drawn up by Dr Hiraga, the leading naval architect of the Imperial Japanese Navy.

On 4 November 1937, the first battleship's construction began and the keel was laid down in the dry dock of the Kure Kaigun Kōshō shipyard. 'Warship No.1' was later given the name *Yamato* – a mystic and especially potent name for the largest and most powerful battleship ever built.

Yamato is Japan's oldest poetic name, the name of the territory on which the first seed of the Japanese state was sown, and it later became the name of the province on the Kii peninsula, in south-western Honshu, whose capital is Nara.

Throughout the Second World War, *Yamato* was not only Japan's most modern new-generation battleship, it was also the pride and symbol of its Imperial Navy. Her loss in the operation 'Ten ichi go', in April 1945, became a symbol of the downfall of the Japanese Empire and was a final confirmation of the eclipse of the world's floating fortresses.
Originally built to oppose US battleships – with the capability to annihilate them in battle – *Yamato* and her sister ship *Musashi* never in fact fought against them.

Both these giant battleships were sunk by the planes of the US carrier forces – as revolutionary changes in sea warfare tactics, these carrier planes became the fleet's main force of attack, giving battleships in some measure an auxiliary function.

When the Bureau of Naval Construction began to make plans for a new battleship in 1934, there was no forewarning of the near supremacy of naval air forces and so she was designed to more strongly reflect the Tsushima tradition and the sea battles of the First World War.

In the Fifth Replenishment Program of 1942 two new warships No.798 and No.799 were projected. They were to have been battleships of a new design, armed with 50.8cm (20 inch)/45cal guns. The last version (Design A-150) featured 50.8cm guns in three twin turrets and many 10.0cm/65 cal HA guns as a secondary battery. The giant gun was constructed in early in 1941 in Kure Navy Yard and tests were made in the same year. The AP shell would have weighed about 2000kg. Battleship No.798 was to have been built at Yokosuka and No. 799 at Kure and laid down in late 1941 or early in 1942, with a total building period of some five years. They were in some ways similar to the *Yamato* class, but the design drawings were destroyed after surrender.

BUILDING HISTORY

Work on the *Yamato* project began with the development and modernisation of four selected shipyards – Kure, Nagasaki, Yokosuka and Sasebo – in which the future ships were to be built, because at that time none of the Japanese

shipyards could undertake the building of such gigantic hulls.

Yamato was built in Kure Kaigun Kōshō in Kure naval yard's drydock which was extended by a metre and protected by a special roof on one side to screen her from view from the nearby hill. A gantry crane straddling the dock was used to lift parts weighing more than 100 tons.

A new dock in Yokosuka was built for *Shinano*.

Musashi was built in the Nagasaki naval yard. A sisal rope curtain hid the slipway on which the hull was built from view; the rope was 2710 km long and weighed 408 tons.

Musashi's launch – her hull weight on the slipway was 35,737 tons – was second only to the 37,287 tons of the British passenger liner *Queen Mary*.

The fourth battleship, No.111, which was never completed, was laid down in a new dry dock at Sasebo naval base.

The gigantic 46cm guns and their turrets, manufactured at Kure, were transported by the *Kashino,* a ship built specially for the purpose (displacement 11,000 tons, dimensions 135.0m x 18.8m x 6.7m).

The design works began in October 1934, and in March 1937 the design was finalised.

HULL STRUCTURE

The research and design work was carried out simultaneously with the hull model tests, the main aim of which was to reduce hull resistance and increase propulsive efficiency.

As many as 50 experimental hull models were built and tested in the experimental model basin of the Naval Technical Research Centre in Tokyo. This was then the largest basin of its type in Japan with a length of 245.5m, a width of 12.5m and a depth of 6.5m.

The results of these experiments led to the adoption of a gigantic bulbous bow of such a size and shape that it was unique in the contemporary world. The stern part of the hull was based on the sharp geometric form of the oldest Japanese battleships.

I discovered this sharp form from photographs analysed in about 1995, and the expedition in 1999 confirmed this shape, as did Paul G. Allen's last examination of the *Musashi*.

Principal dimensions of *Yamato* in 1941	
Length overall	263.0m
Length waterline	256.0m
Length between perpendiculars	244.0m
Beam	38.9m max
Beam waterline	36.9m
Draught (trial)	10.4m
Draught (full load)	10.86m
Displacement:	65,000 tons standard
	69,100 tons trial
	72,809 tons full load
Shaft horsepower	153,553 (astern 45,000)
Speed	27.46 kts
Oil fuel capacity	6300 tons
Range in action	7200 nm at 16 knots
Propulsion plant	4 steam turbines
Steam pressure	25kg/cm^2
Temperature	325°C
Armour	75–410mm side belt
	200–230 deck
	190–650 main turrets
	380–560 barbettes
	50mm secondary turrets
Armament	9 x 46cm (18.1in) triple turrets
	12 x 15.5cm (6.1in) triple turrets
	12 x 12.7cm (5in) twin mountings
	24 x 25mm MG triple mounting
	4 x 13mm MG twin mountings
Aircraft	6 (max7) floatplanes
Crew	2500

Thanks to a unique solution, the hull resistance was reduced to 8.2 per cent at a speed of 27 knots, and by improving the fitting of the shaft bracket and the bilge keel, a further reduction was achieved. In terms of effective horsepower, the former alteration resulted in a saving of 1900ehp and the latter in one of 475ehp. Altogether, including the reduction in hull resistance by use of the bulbous bow, sharp stern shape, the saving totalled 7910ehp, or 15,820shp.

In the full-power trial run the 69,100 ton ship, powered by 153,533shp, reached a speed of 27.46 knots (Japanese sources from the late 20th century

Yamato *during her full-power trial on 20 October 1941, outside Sakumo Bay. According to information from crewmen, several years after the war, perhaps at that moment the battleship had reached a speed of more than 30 knots.*

increased the power of the *Musashi* to 166,520shp and her speed to 28,50 knots).

Yamato's hull was broad and had a relatively shallow draught for a ship with such large displacement (10.86m fully loaded). It meant that the *Yamato* class ships could use the naval bases and dry docks of the Imperial Japanese Navy without extra money being spent dredging or rebuilding.

Another very important feature of *Yamato*'s hull was the method by which the shell plating was joined – namely, the extensive use of lap joints amidships. The butt joint had long been used in shell plating to make the shell surface smooth, reducing its frictional resistance. However, a serious defect had been found in the outer bottom plates of the *Isuzu* class light cruiser and *Fubuki* class destroyers which gave cause for concern over the use of butt-jointed plates in *Yamato*. It was discovered that frictional resistance was greatly affected by the surface of the fore and after parts of a ship where the water pressure was greater than at amidships.

Based on this finding, butt-joint plating was used only in the fore and after parts of *Yamato*, the remaining sections being covered by lap-joint plating. The method proved very effective when the ship was completed.

In the course of constructing *Yamato*'s huge hull, two factors – apparently contradictory – played an important part. The designers wanted to increase its strength and at the same time reduce the hull weight, for which the introduction of new methods was required. Dr. Hiraga applied the method that had earlier been used for the heavy cruiser *Furutaka,* whereby the armour-plating not only served as protection against hits, but was also an integral part of the hull construction. The thickness and rigidity of the armour-plating reinforced the hull strength considerably compared with traditional methods in which the armour merely was added on. This unique method was quite an innovation in international warship-building circles at the time.

Another considerable saving in hull weight was achieved by using electric welding extensively and on a large scale except in such important features as longitudinal members. The technique had not been fully adopted because welded joints on smaller warships built earlier had been found to be weak in comparison with the traditional riveted joints. The Japanese Navy was relatively early in its adoption of electric welding. It was used more widely in the construction of *Yamato*'s upper structure and superstructure than in the hull.

– The largest welded block was 11m high and weighed 80 tons.
– On the hull, the length of the welded joints was 343,422m – and the number of electrodes 5,995,611.
– On fitting and equipment – 120,347m / 1,511,298 electrodes.
– Protection – 15m / 636 electrodes.
– Total length of welded joints was 463,784m / 7,507,536 electrodes.
– Number of rivets used was 6,153,030. For example in building the battleship *Mutsu,* 3,733,753 rivets, were used and in battleship *Hiei* 2,874,622.

Another feature was that the main portion of the longitudinal structure was made with Ducol steel (DS) – the central longitudinal bulkhead was constructed in duplicate – to support the heavy 200–230mm plates plus 9mm DS deck plating. The deck extended to a width of 38.9m – the maximum width of the ship. To ensure the reliability of the electric services, the central ring main electric circuit ran through the watertight compartment inside the central bulkhead.

The weather deck – flush, with an untypical bottle-shape in plan – had its own uniquely characteristic undulating profile. The extremely effective idea of using longitudinal framing – it minimised the structural weight – was another of Dr. Hiraga's innovative methods which had been applied for the first time to the heavy cruiser *Furutaka*.

The characteristic shape of *Yamato*'s bow came from the necessity of moving the hawse pipe away from the ship's centre line and as far forward as possible in order to protect the bulbous bow from being damaged by anchors. The lowering of the deck, starting from frame 110 towards the bow, was also connected to the reduction in weight and to the ship's profile.

The boat hangars, which were installed on both sides of the hull aft, were equipped with a single girder crane to lower boats directly to the water and gave the hull a modern and unusual appearance for that time. The middle part of the weather deck was covered with wooden 140mm-wide planking. The planks were made from Japanese 'hinoki' cypress.

The aircraft deck, starting from frame 177 towards the stern, was covered by steel plate partially chequered and reinforced by concrete (under steel plates).

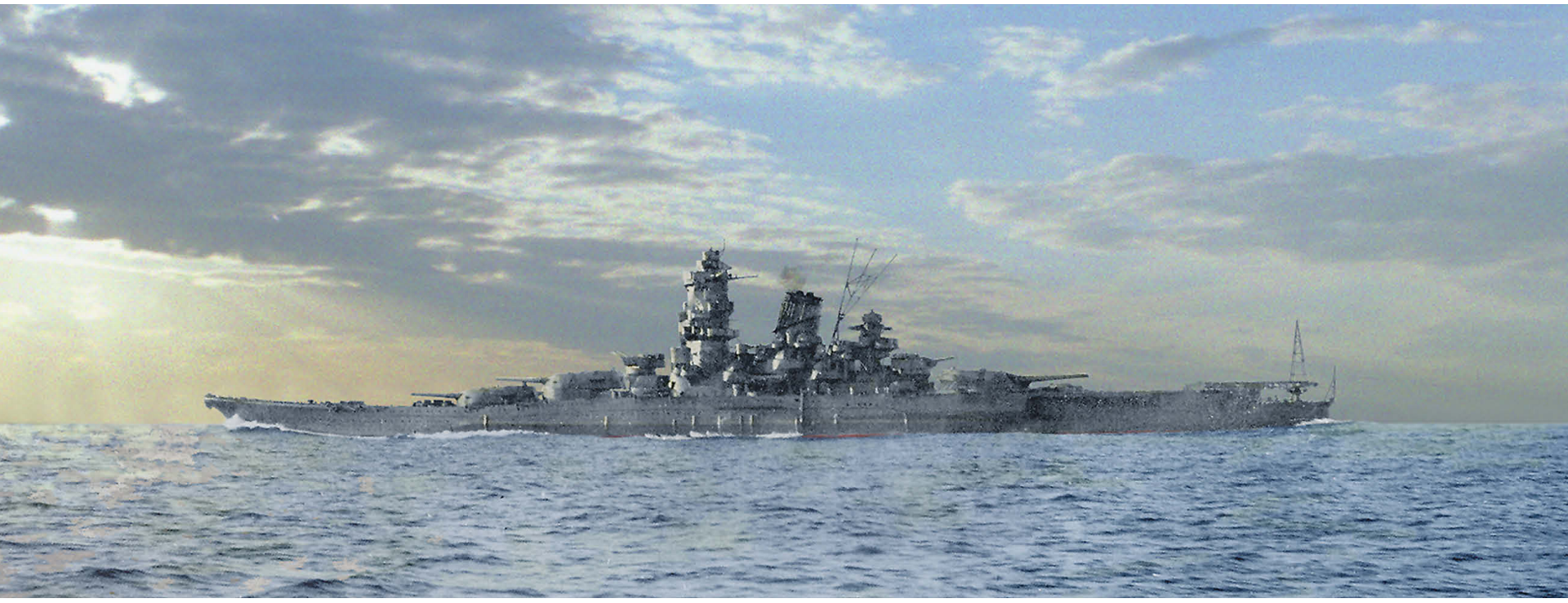
The metal decks – including the anchor deck, part of the superstructure decks and the stern deck were all covered with chequer plating. The chequered plates of the anchor deck were not painted but made of zinc-galvanised steel plates.

The characteristic feature of the decks compared with other battleships was that they were 'empty' – without equipment. This was because of the terrific blast from the 46cm guns.

Ventilators and ventilation openings were constructed and placed in such a way as to avoid or reduce the effect of the blast. The necessary equipment, such as boats, planes and paravane, was kept in completely protected magazines or hangars. The construction and shape of the superstructure sides, the lack of platforms plate supports, and the protection of anti-aircraft batteries and observation and machine-gun control positions by shields were also to reduce blast for its crew. Later on, the open HA and MG stands were manned only when the main 46cm guns were not in action.

Blast pressure (kg/cm²) relative to gun distance				
Calibre	15.5cm		46cm	
Distance	1 barrel	3 barrels	1 barrel	3 barrels
5m	2.1	2.5	10.0	20.0
10m	0.95	1.6	5.8	11.0
15m	0.5	1.15	3.1	7.0

Yamato *in 1942; this photo was found about 50 years after the end of the war.*



Yamato *during a trial run on 26 October 1941.*

A blast pressure of 0.28kg/cm^2 was capable of destroying the boats on board ship and a blast pressure of 1.16 kg/cm^2 was strong enough to tear the clothing from crew and render them temporarily unconscious. These pressures (1.16 kg/cm^3) were felt 30m away from the one-barrel 46cm guns and 50m away from the three-barrel 46cm guns.

***Yamato* weight breakdown, trial conditions**			
	Tons	Tonnes	Percentage
Hull	20,212	20,536	29.2
Armour	21,266	21,807	30.8
Protection	1,629	1,665	2.4
Gun	11,661	11,849	16.9
Machinery	5,300	5,385	7.7
Fittings	1,756	1,784	2.5
Fixed equipment	417	424	0.6
Consumable stores	641	651	0.9
Navigation and optical	95	97	0.1
Electric	1,108	1,125	1.6
Aircraft	111	113	0.2
Pressurised water in boilers	297	302	0.4
Fuel oil	4,210	4,278	8.1
Reserve feed water	212	215	0.3
Lubricating oil	61	62	0.1
Light oil	48	49	0.1
Total	**69,100**	**70,209**	**100**

SUPERSTRUCTURE

The superstructure was positioned like an island on the huge deck of the battleship.

Its shape differed considerably from the superstructures of the older ships of the Imperial Japanese Navy. The tower – the characteristic 'pagoda mast' – was built as a result of the modernisation and rebuilding of the front tripod mast, which formed the core of their construction.

On the *Yamato* three features rose from the streamlined lower part of the superstructure with sloping sides – the tower bridge under the 15.5m rangefinder, the funnel uptakes and the after tower under the 10m rangefinder. The tower bridge and after tower were constructed around concentric cylinders; the tower bridge from three and rear tower from two.

The inner 1.5m diameter cylinder of both towers was made of 20mm thick DS, inside of which ran the communication lines. On top of these cylinders were Type 98 'Hoiban' low-angle directors in non-rotatable armoured mounting with three 12cm binocular stands and a periscope tower on top. In the space between the cylinders were fitted passages, staff briefing rooms etc. *Yamato*'s tower bridge area was 159m^2 (front) and 310m^2 (side) and was smaller than 'pagoda masts' on older Japanese battleships.

The tower bridge posts and rooms had been tested on the battleship *Hiei* – it was especially for that purpose that the the 'pagoda mast' was rebuilt, as a prototype for the *Yamato* class. After the necessary alterations, the tower bridge for the battleship was finally designed.

The main parts of the superstructure and tower bridge were protected by 20mm armour-plating capable of withstanding the force of projectiles from enemy aircraft.

ARMOUR

The weight of *Yamato*'s armour protection was 22,895 tons – the heaviest armoured ship ever built and a record that has not yet been broken. Her main section was protected by a sort of colossal armoured box. The box sides were protected at the top by 410mm Vickers hardened (VH) armour-plating, which was designed to withstand 46cm armour-piercing (AP) projectiles fired from distance of more than 20,000m. The front and back of the box were protected by 340–300mm VH steel armour. From above the armour deck (on the middle deck of the ship), made of MNC (New Vickers – non-cemented) steel armour-plating 200–230mm thick, formed protection against 46cm AP projectiles fired from a distance of 30,000m and could be penetrated only by a 1000kg AP bomb dropped from a height of 3400m or more.

A view of Musashi *from the anchor deck during trials in May–June 1942.*

Another feature was the 9mm DS plating that extended 700mm beneath the armour deck. Its purpose was to protect against possible splinters such as those from armour bolts and rivet heads when the armour deck was hit by a bomb or projectile.

Even part of the fore and after weather deck, in addition to the armoured main section, was protected by 35–50mm CNC (copper alloy – non cemented) steel which was sufficient to repel a 250kg bomb dropped by an enemy dive-bomber. The real achievement of *Yamato*'s design was the fact that the constructors managed to reduce the length of the main box-protected section vitals to 53.5 per cent of the total length. Despite her lower ratio, *Yamato*'s stability in damaged conditions was designed to be better than that of other Japanese capital ships. Heavy armour also protected two steering-engine rooms – for the main and auxiliary rudders – which were situated outside the main armoured section of the ship. They consisted of two armoured boxes: the sides of the main rudder room were protected by 350–360 VC armour, the top part by 200mm MNC and the auxiliary rudder by 250–300mm VC.

Another feature was the fact that the floors of the ammunition magazines were protected by 50–80mm armour-plating which extended from the bottom of the magazines across watertight compartments above the double bottom of the hull shell. The idea was to protect them from explosion from a hostile torpedo or mine beneath the ship.

A new method of armour protection was also adopted for the boiler uptakes. Funnel gases escaped through perforated plates that were adopted after careful tests proved that they reduced the weight of armour compared with conventional grating armour. The 380mm armour-plating was perforated with holes of 180mm diameter (the total area of the holes being less than 55 per cent of the whole plating area). In addition, the inclined surfaces of the funnel were protected by 50mm armour which would detonate bombs before they reached the surface of the perforated plating.

As mentioned previously, *Yamato*'s armour protection was designed to resist the terrific kinetic energy of 46cm projectiles weighing 1460kg and travelling at approximately 500m/sec.

This was the calibre of both *Yamato*'s own, and her sister *Musashi*'s, artillery that was never actually employed on other ships. Such requirements demanded the perfection of new technologies to avoid the increase in thickness of the armour-plating. The builders could not apply the type of steel that had been used before; it took as many as ten years of research and development to solve the problem. An extremely hard surface was a requisite requirement for the armour-plating, but the ordinary method of cementation was expensive and could not achieve the desired plate thickness. A special method was adopted to harden the surface of the thick armour plates, which proved very effective: not only could it harden a portion as far as 140mm into the plate, it also greatly reduced production costs.

The next step was the adoption of armour-plating of larger dimensions, a development connected with the reduction in the number of edges and joints exposed to projectile hits.

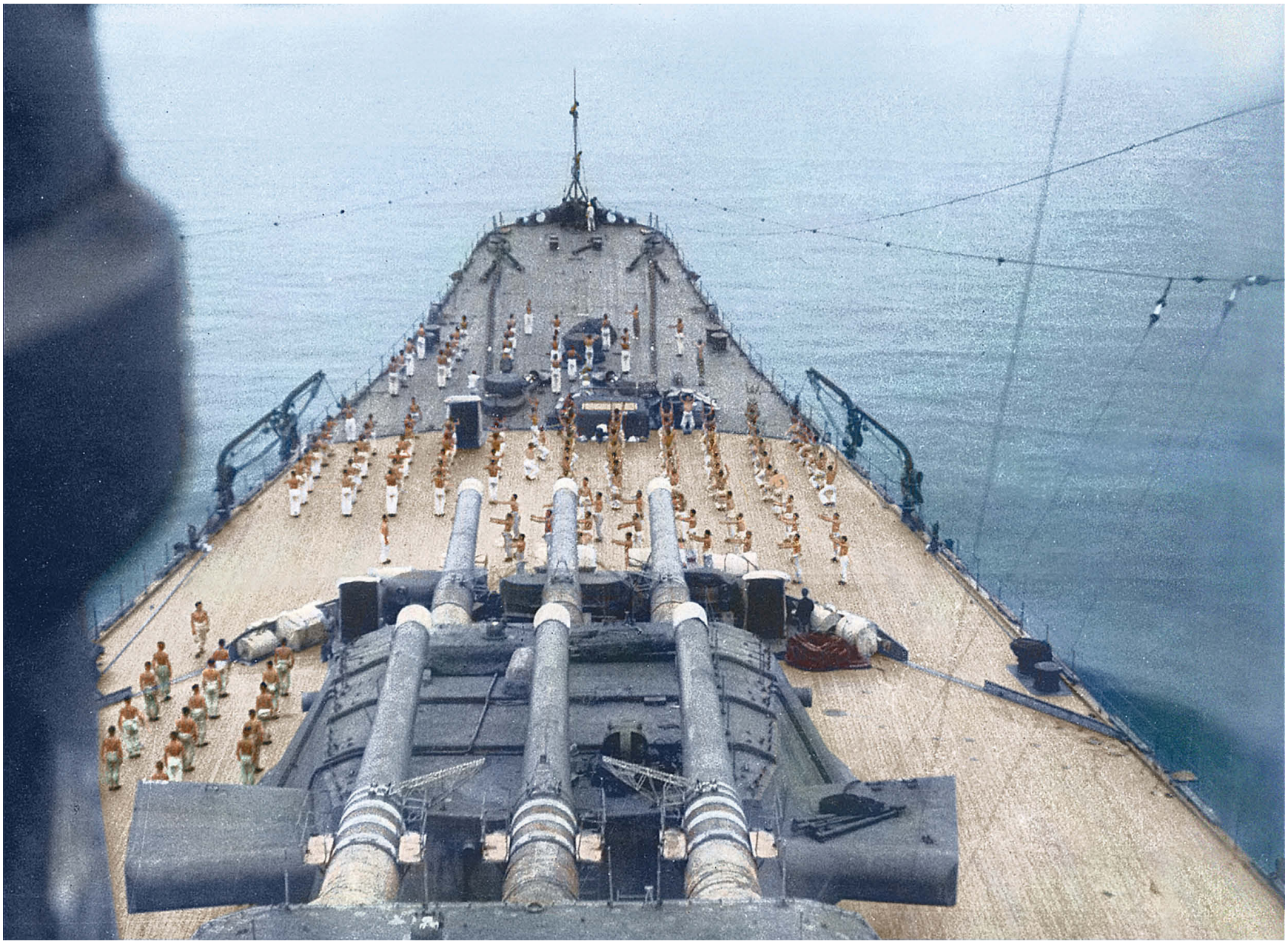
The Japanese Navy ignored the expense involved in expanding the necessary facilities to manufacture larger pieces of armour for the *Yamato*-class battleships. According to records, about $10,000,000 (US) were spent on expanding steel-plate manufacturing facilities. As a result, the dimensions of the side armour plates were: thickness 410mm; length 5.9m; width 3.6m = 21.2m^2; weight 68.5 tons.

Another problem was the emplacement of the armour, particularly the lower edge of the 410mm side armour, so that it could withstand a hit. Side armour was equipped so as to drive a wedge with an angle of 10° at its lower edge when struck by the shock of a hit, but in the event this method proved insufficient after she was commissioned into service. The underwater protection system was based on a lot of tests carried out on 1:3 scale models by means of well-chosen explosive charges. The last test was carried out in 1939 on a full-scale mock-up of *Yamato* that was attacked with 400kg charges. The holding bulkhead did not remain watertight but was not split open. The principal weakness was at the bottom connection between the holding bulkhead and the shell, and this section was redesigned for *Yamato*.

Prior to construction, however, considerations of underwater projectile trajectories meant that the bulkhead was radically increased in thickness. As installed, it was 200mm thick at the top (the connection with the lower edge of the 410mm main side belt) to 75mm at the bottom connection with the shell – the entire system being designed to withstand an attack by a 400kg charge.

The biggest problem with the change in design was the method for connecting the main armour belt with the newly designed lower torpedo-holding bulkhead. The decision was an unsatisfactory compromise reached over the objection of several officers who felt a delay in completion of the ship was warranted in view of the problems already apparent in the design.

The design of the joint was based primarily on the ability of steelmakers to produce the special shapes required in a reasonable amount of time. That joint was the weak point – and a significant design error – as it was entirely dependent for transfer strength on the shearing strength of tap rivets and three-ply rivets. The joint itself did not give adequate support in the transverse direction.



View from Musashi*'s tower bridge to the anchor deck, forecastle deck and main gun turrets no.1 and no.2. On the left is part of the 1.5m navigation rangefinder. Small trusses on the left and right barrels and small platforms were fitted temporarily for precise adjustment of the guns.*

The aforementioned fears were confirmed by damage to *Yamato* from a single torpedo hit on the starboard quarter, from a torpedo fired from a submarine, on 25 December 1943. A hole about 5m deep, extending downward from the top of the bulge connection (of the armour), and 25m long, between frames 151 and 173, was produced, Water flooded into the No.3 turret upper magazine from a small hole in the longitudinal bulkhead caused by the caving in of the waterline armour.

As a result of the Japanese investigation into this damage, the Fourth Section, Ship Construction, authorised the installation of a 45° sloping plate across the corner of the upper void between the two inboard bulkheads during the January–April refit.

View from Musashi's *tower bridge to the funnel, main mast and aircraft deck in May 1942, during finishing works; the two boats visible were fitted only temporarily.*

Yamato's hull was divided into 1147 watertight compartments (WTC) that comprised 1065 below the armour deck (middle deck) and 82 above. The maximum extension of the WTC increased her buoyancy. Her reserve buoyancy reached as much as 57,450 tons (c.f. 29,292 tons for *Nagato*, 21,300 tons for *Fusō*) – this was 80 per cent (67.6 per cent for *Nagato*, 55.2 per cent for *Fusō*) of her trial displacement. The battleship was also designed to remain fairly stable when in a damaged condition.

In the event of her bow or stern sections, other than the armoured citadel, being flooded, it was believed that she could maintain her stability until she listed to 20˚, and that her trim capacity would enable her to function with her freeboard forward reduced to 4.5m – *Yamato*'s fore freeboard was 10.0m, amidships 8.6m, and after 6.4m – even if her fore part was completely destroyed and flooded.

FLOODING AND PUMPING SYSTEM

The flooding and pumping system was designed to fulfil the following requirements:

1. The resultant list and trim from the first torpedo hit should be reduced to under 4˚ list and 2.3m difference in draught fore and after within five minutes of the damage control system going into action.

2. The resultant list and trim from the second torpedo hit should be controlled within thirty minutes, to the above-mentioned standard.

By flooding the opposite damage control tanks, the battleship could also be heeled by 13.8˚ maximum, and another 4.5˚ list could be added by shifting fuel to the opposite fuel tanks. Altogether, it was believed that the system could enable the battleship to return to almost even keel from a list of 18.3˚.

MACHINERY

The designers abandoned mixed propulsion (diesel plus turbine) in the last phase of the project.

The battleship was equipped with 150,000hp turbine propulsion machinery using 25kg/cm^2 and 325˚C steam. Twelve boilers, each of 12,500hp, were set up in four rows, three per row, and each located in a separate room. Three boilers in a row propelled each turbine. The Kampon-type boilers were of a standard Japanese Navy design. The banks were nineteen tubes deep with superheaters – which were of the two-pass four-loop type – between inner boiler rows 7 and 8. A peculiarity of Japanese naval boilers was the narrowing of the bank of tubes between the furnace and superheaters. The centre-to-centre length of the first inner rows was 4.25m and rows 4 to 7 were reduced so that the distance between the the superheaters and beyond the passage was only 3.263m. *Yamato*'s boiler rooms had a floor area of 798m^2 and an engine room floor area of 640m^2 = 238shp/m^2. The ship's prismatic coefficient was 0.612 and the block coefficient 0.596.

At maximum speed, when all twelve boilers were in operation, the consumption of fuel oil amounted to 62.700kg/hr = 1233 kg per 1000m of the distance steamed.

Using full power of 153,553shp she reached a maximum speed of 27.46 knots; at a standard (economic) speed 16.47 knots she used 18,596shp with a maximum radius of 7200 nautical miles – all with 4,210 tons of fuel oil on board.

All this data concerning maximum propulsion by steam turbines and maximum speed became available to the public several years after the end of the war. More than 12 years ago new data was published: maximum power 166,520shp with a maximum speed of 28.1 knots for *Yamato*'s sister ship *Musashi*.

The last preliminary design for the superbattleship A-140-F3 – just before the design of the *Yamato* class – reached 135,000shp, 65,200 tons trial displacement, dimensions of the hull the same as *Yamato* – maximum speed 27 knots.

Maybe the previously mentioned speed of over 30 knots during trials in December 1941 is not merely a report and can be assumed to be real.

TURNING ABILITY

The ship's turning ability was also superior compared with other battleships. *Yamato*'s tactical diameter was 640m, the advance diameter 589m, giving a maximum heel of 9˚ when the ship was turned by the maximum rudder angle of 35˚ at a speed of 26 knots. The small heeling angle in a turn (necessary from the point of view of evading bombs and torpedoes, and for stability and fire control) was attributed to her metacentric height – GM = 2.88m during trials. Her rolling period was an impressively steady 17.5 seconds.

The battleship had two rudders – main and auxiliary – respectively 46m^2 and 17m^2, instead of the twin-rudder system of ordinary large warships. Originally it was planned to install two rudders, one each fore and aft, but the plan was later changed to fit the auxiliary rudder about 15m ahead of the main. In the trial run, however, an unexpected attribute of the auxiliary rudder was discovered, to the disappointment of the designers: so great was the turning momentum of the ship once she had begun to alter course that the auxiliary rudder alone could not reduce the momentum sufficiently to make her resume her course.

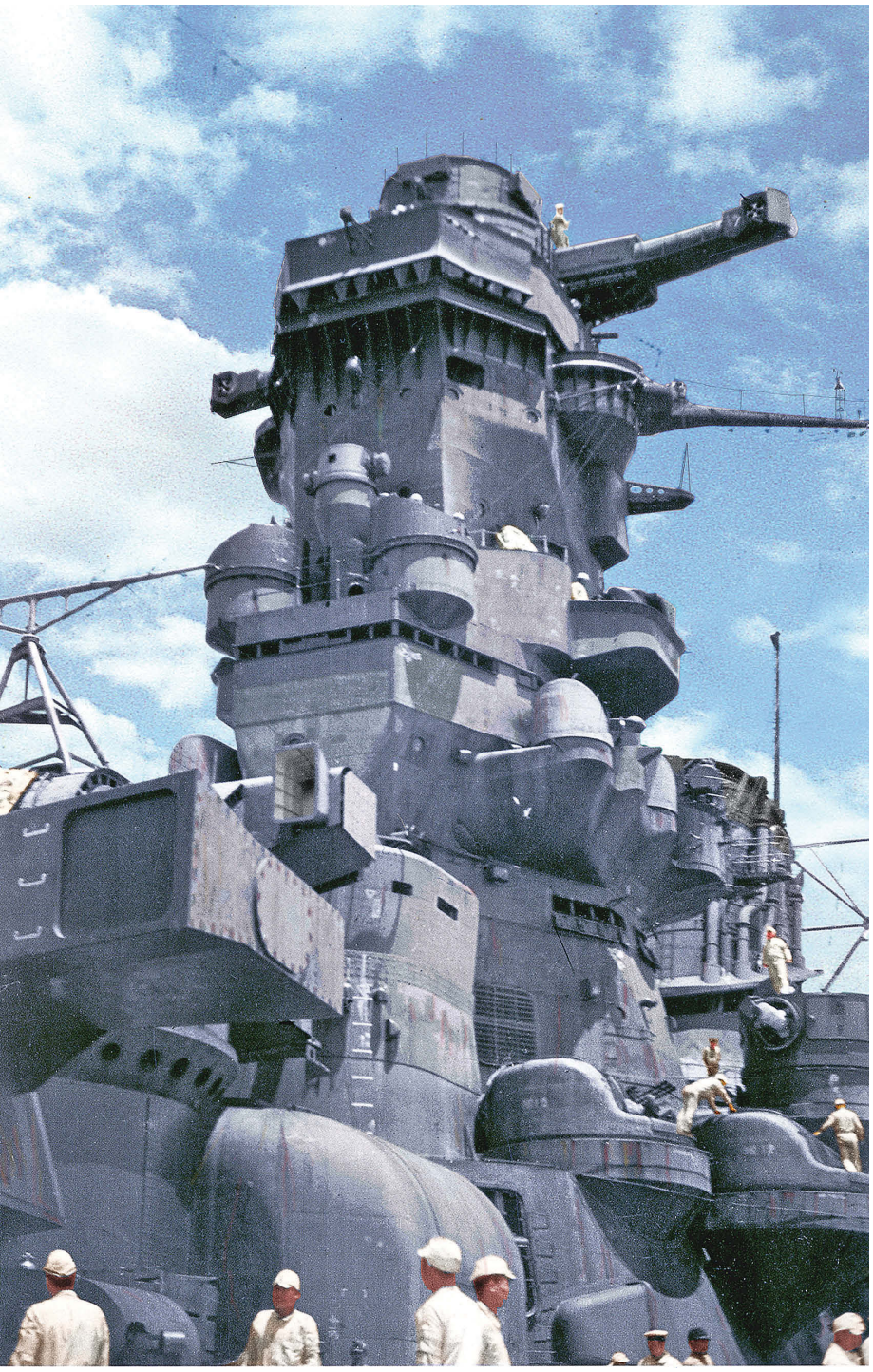
ARMAMENT

Main armament – Type 94 46cm/45 calibre guns

The 46cm (18.1in) guns with which *Yamato* and *Musashi* were supplied were the only modern guns of this calibre ever mounted in a ship and represented quite an achievement for the Imperial Japanese Navy. Up to that time 40.6cm (16in) guns were the largest in general use, the only exception being the British battlecruiser *Furious* that was equipped for a short time with two single turrets with 45.7cm Model 1915 guns. Japanese designers had been interested in using very large guns since 1920; the 13–16 class battleships from 8–8 Project's cancelled programme were to be equipped with 46cm guns and at the same time they were testing 48cm (18.9in) guns. In 1934 the building programme for modern 46cm guns was restarted with a view to the new superbattleships. The new guns – being perfected by the engineer C. Hada's team – were ready in 1939 and their production started in 1939–40.

Twenty-seven guns were built, of which 18 – six complete turrets – were mounted in *Yamato* and *Musashi*. The maximum weight of a triple turret was 2774 tonnes – about as heavy as a big destroyer. The AP projectile's 1460kg weight was one and a half times the weight of the 40.6cm projectiles.

Building these modern guns was extremely expensive and the designers had to solve a lot of new technical problems. However, the Japanese naval strategists' policy was to make each individual ship so powerful that even the resource-rich industrial United States would scarcely be able to match them.



The tower bridge of Musashi *during finishing works in May–June 1942. This photograph was taken from the main deck.*

Shell rooms, hoists and ram mechanisms

The number of projectiles per gun was 130 rounds, of which 60 projectiles were stowed in the turret rotating structure, making 180 projectiles in the turrets (3 x 60). The remainder – 70 projectiles per gun, 210 per turret – were located in the shell rooms. So altogether the ship had 1170 projectiles and the same amount of 330kg powder charges.

It was considered that 60 projectiles per gun was sufficient for battle; while fighting, it was possible to supply the turret rotating structure with projectiles from the shell room, but it was quite a time-consuming process. The projectiles were moved by means of 'push-pull' gear: the projectiles in the turret were moved directly to the hoist (a simple 'pusher type' on a 5° downward-tilting platform for transfer to the hoist proper). The hoist door closed automatically by a spring-loaded crank activated by the weight of the projectile entering the hoist mechanism, and the projectile was seated on the hoist, which was fitted with a set of three lifting and retaining pawls, back and front respectively. When the projectile reached the top of the hoist, it was carried into the tilting bucket (tilted 8° upwards) and held in the bucket by clips. When the projectile was ready, it was moved from the bucket into the waiting tray before its transfer into the shell-loading bogie and rammer. The loading bogie moved forward on rails, at the same time lowering into the gun load angle of 3°. After the gun had been loaded the shell rammer (chain) was taken back and the powder charge loaded.

Magazine and cordite handling room

Each of the three turrets had two cordite magazines. The lower room had one transfer bogie and one hoist servicing the centre gun; the upper room had two bogies and two hoists for the left and right guns. The entire propellant charge weighed 330kg – six charges each of 55kg.

These were stowed in magazines in flash-tight stowage canisters (two charges per canister) from where they were removed and passed through flash-tight scuttles controlled by the cordite roller chute and into the turret rotating structure. A full charge (six 1/6 charges) was then transferred to the cordite hoist cages via the transfer bogie pivot tray. Each end of the hoist had a flash-tight door that was operated by a combination of cams and hand levers.

Opening the upper flash door freed the rammer control. The cordite hoist was a flash-tight 2870 x 950mm trunk equipped to take one cordite cage. The cordite cage was supplied with a flash-tight container for the entire charge (330kg) that was opened at the same time as the charge was loaded into the gun chamber by a cordite rammer (similar in construction to the shell rammer). At low elevation (~20°) a 28-second firing cycle was possible, and 40 seconds for the maximum 45° elevation.

Train and elevation engine

Each turret was equipped with two sets of training gears, only one being used at a time. Contrary to previous Japanese practice, a worm gear was rejected because of space limitations and a rack and pinion system adopted. Each turret was equipped with two 500hp hydraulic motors for train drive – one for each set of gears.

Each gun was fitted with elevating and shifting cylinders. The rotation rate was 2˚/sec, elevation rate 10˚/sec, maximum elevation +45˚, loading and underway (normal) position +3˚, and minimum elevation –5˚.

Each turret was equipped with auxiliary hoists with overhead travellers and chain purchase for emergency handling in the gunhouse. Hydraulic winches were used to move the projectiles to the hoists in emergencies; hydraulic valves allowed the magazines to be flooded completely in 20 minutes. Each powder magazine and shell room was equipped with sprinklers.

Gunhouse

Each turret was divided into four compartments, each comprising three guns plus equipment placed in a separate cell. The separate compartment behind the gunhouse was occupied by a 15m turret rangefinder. The armour protection was as follows:

Gunhouse: front 650mm, side 250mm (minimum), back 190mm, roof 270mm.
Barbette: 560mm – 380–440mm after parts.

46cm gun performance		
Elevation	Range (m)	Projectile flight time (sec)
10˚	16,843	26.05
20˚	27,916	49.21
30˚	35,826	70.27
40˚	40,700	89.42
45˚	42,026	98.60

Power against targets at various ranges		
Range (m)	20,000	30,000
Gun elevation	12˚ 34’	23˚ 12’
Striking angle	16˚ 31’	31˚ 21’
Striking velocity	522m/sec	475m/sec
Penetration vertical plate	566mm	467mm
Penetration horizontal plate	416mm	230mm

Gun data	
Designation	Type 94 46cm/45cal
Calibre	46cm (18in)
Length in calibres	45
Length overall	21,300mm
Construction type: wire wound radially expanded muzzle	4 layers
Breech	5 layers
Breech type	screw
Rifling No. of grooves Twist uniform Groove depth	 72 1 in 28cal 4.6mm
Bore cross-section	1698cm^2
Projectile range	17.59m
Chamber volume	480 litres
Diameter of turret rollers (axle)	12.274mm
Distance from centre of rotation to trunnions in fore and aft line	3520mm
Height from centre line of guns to roller path	4400mm
Distance between centre line of guns	3050mm
Recoil length	1430mm
Ventilation	Three 2.5hp fans for supply and five 5hp exhaust fans
Turret rangefinder	15.5m base, elevation +10˚ and free train 160 milsec right, 130 milsec left
Local sight	One 10cm telescope per gun
Spreads	Normal spreads in 4- or 5-gun salvoes at maximum range, about 500–600m; somewhat larger in broadside firing

Note the details of the No.1 main gun turret; periscope of the right gun and the 15.5m turret's rangefinder arm with closed opening and a sliding steel screen.

46cm gun mount data (weight in tonnes)	
Rotating turret structure:	
Three guns with breech mechanisms	495
Remainder of elevating parts	228
Turntable minus elevating parts and armour	350
Remainder of training parts below turntable	647
Gunhouse armour	790
Total weight	**2510**
Total weight with ammunition	**2774**

Projectiles

Three basic types of projectile were used in 46cm guns:

1. Armour piercing (Type 91). This weighed 1460kg and was designed to enter the water short of the target, maintain its trajectory and penetrate the hull's torpedo defence system. The projectile nose was given a hydrodynamic shape so its trajectory would not alter drastically on entry. The Japanese had been quite impressed by the damage caused by rounds falling short on their partially completed battleship *Tosa* in firing experiments.

2. 46cm type common 'San Shiki' Model 3. This was originally constructed and designed as AA, acting as an incendiary 'shotgun' projectile. It was fitted with 900 incendiary tubes (rubber thermite) and 600 steel stays. The projectile was supplied with a time fuze set to go off at suitable height when the contents of 1500 incendiary tubes and stays exploded in a cone shape in an angle of about 20˚ towards any incoming aircraft. In a fraction of a second after firing, the projectile shell was destroyed by a bursting charge, increasing the quantity of shell splinters. The incendiary tubes ignited about half a second later and burned for five seconds at 3000˚C, giving a flame about 5m long.

3. Type HE (high explosive). This weighed 1360kg and contained 136lb of tri-nitro-anisole (TNA).

46cm projectile data	
Muzzle velocity (AP projectile)	780m/sec
Muzzle velocity ('San Shiki', HE projectile)	805m/sec
Maximum range (AP projectile)	42,050m
Maximum altitude	11,900m
Barrel life (approx)	200–250 service rounds
Bore pressure	32kg/mm^2

Secondary Armament

This consisted of 'Nendo Shiki' (Third Year Type) 15.5cm/60cal guns. Engineer C. Hada designed the 15.5cm guns (as well as the 46cm guns) in 1932 as the main armament for 'B' class cruisers; they were also mounted in the *Mogami* class cruisers. These guns were the finest in use during the Second World War. *Yamato* and *Musashi* originally had four 15.5cm gun turrets. These triple turrets were made available by the conversion of four *Mogami* class cruisers, which were given twin turrets with 20.3cm guns in place. The triple turrets after modernisation were installed in a diamond arrangement, the turrets in superfiring positions over the main battery fore and aft, and the two others were in wing positions, one on each side. The wing turrets were removed to provide space for additional 12.7cm AA guns for *Yamato* in January 1944 and for *Musashi* in April 1944.

The gun mounts and turrets were operated by electro-hydraulic power with mineral oil as the pressure medium (two 100hp motors per turret). Each turret had six hoists – one shell hoist and one powder hoist per gun. The shell handling room and powder hoist equipment were essentially a scaled down version of large-calibre equipment. The hoists were activated by hydraulic motors supplied by the common ring.

15.5cm gun data	
Bore calibre	15.5cm (6.1in)
Length	60cal
Barrel length (overall)	9615mm
Construction	Monoblock radially expanded
Breech mechanism	Normal swinging – hand or hydraulic
Weight with breech	12.7 tonnes
Groove number	40, twist uniform: 1 in 28cal
Chamber length	1129mm
Chamber volume	38 litres
Muzzle velocity	980m/sec
Bore pressure	34kg/mm^2
Barrel life	250–300 rounds
Firing rate	7–5 rounds/min
Maximum range (45˚) AP	27,400m
Maximum range (common)	26,500m
Maximum altitude	12,600m
Elevation/depression	55˚/ – 10˚
Projectile weight	55.87kg (all types)
Charge weight	19.5kg
Normal ammunition supply	150 rounds per gun (max 270 per gun)
One 8m rangefinder per turret	

High Angle Guns

As completed, *Yamato* and her sister ship *Musashi* carried twelve Type 89 Model A-1-3 40cal 12.7cm guns in six twin-enclosed mountings. The original shields were enclosed to reduce the effect of the terrific blast from the main 46cm guns. During the ship's refit in January – April 1944 *Yamato* received an extra twin mounting (Type 89 Model A-1 12.7cm/40cal without anti blast protection – it is on open stands) that were installed on existing Model A-1-3 position. The guns with enclosed mountings (towers) were moved to both sides on fitted new superstructure base.

The same modernisation was planned for the *Musashi*, but by the time of the war, difficulties meant that although she had received the additional superstructures on both sides as bases for the 12.7cm and 25mm guns, the six new double 12.7cm guns were not installed, and in its place were fitted six triple 25mm MG on open stands.

The loader's two platforms moved up and down with the elevation of the mounting. The battery was semi-automatic using a spring-operated rammer. There were fuze setters on the right side of each mount. Simple dredger-type hoists were used to lift the fixed ammunition to the gun platform.

12.7cm gun data	
Designation	Type 89 HA 12.7cm/40cal
Length	40cal
Muzzle velocity	725m/sec
Projectile weight	23.05kg
Charge weight	4.0kg
Maximum range	14,800m
Maximum altitude	9400m
Barrel life	800–1500 service rounds
Rate of fire	14 rounds/min maximum 8 rounds/min sustained
Maximum elevation/depression	90˚/–8˚
Construction	Monoblock autofrettaged
Rifling	36 grooves, uniform twist – 1 in 28cal
Ammunition supply (normal)	300 fixed rounds per barrel
Ammunition supply (max)	560 fixed rounds per barrel

Light Anti-Aircraft Guns – Type 96 25mm machine guns

Both battleships were armed with a very successful anti-aircraft gun – Type 96, 25mm/60cal triple machine guns of 1941 design, and after 1943 with single 25mm MG of 1943 design. The guns were similar in construction to the French Hotchkiss type and constituted the main AA weapon of the Imperial Japanese Navy. The triple gun mount was manned by a crew of nine, the single (a free-swinging moveable mount) by a crew of three. The usual ammunition supply was 2000 rounds per gun (one barrel) but by some sources the maximum number of rounds per one barrel in 1945 was 10,000. The 15-round magazines were brought up by hoist to the level of the machine gun platforms, and stowed after in ammunition boxes.

25mm machine guns mounted on *Yamato*		
1941	as completed: 8 x III = 8 closed mounts	24 guns
Sept 1943	4 new triple open mounts = 4 x III + old 8 x III	36 guns
Jan–Apr 1944	12 new triple mounts and 26 new single mounts = total 24 x III + 26 x I	98 guns
July 1944	5 new triple mounts = 5 x III = total 29 x III + 26 x I	113 guns
Jan 1945	21 new triple mounts fitted and 24 single mounts removed = total 50 x III = 2 x I	152 guns
April 1945	4 single mounts fitted = total 50 x III + 2 x I + new 4 x I	156 guns

25mm machine guns mounted on *Musashi*		
1942 as completed	8 x III = eight triple enclosed mounts	24 guns
July 1942	4 x III = twenty new triple open	36 guns
April 1944	18 x III plus 25 x I new mounts (30 x III + 25 x I)	115 guns
June 1944	5 x III new mounts (35 x 3 + 25 x I)	130 guns

25mm machine gun data	
Designation	Type 96 'Shiki' 25mm/60cal MG
Length	60cal
Gun length overall	2420mm
Muzzle velocity	900m/sec
Projectile weight	0.25kg
Maximum range	6800m
Maximum altitude	5000m
Rate of fire	220 rounds/min
Maximum elevation/depression	90˚/ – 10˚

Type 93 13mm machine guns

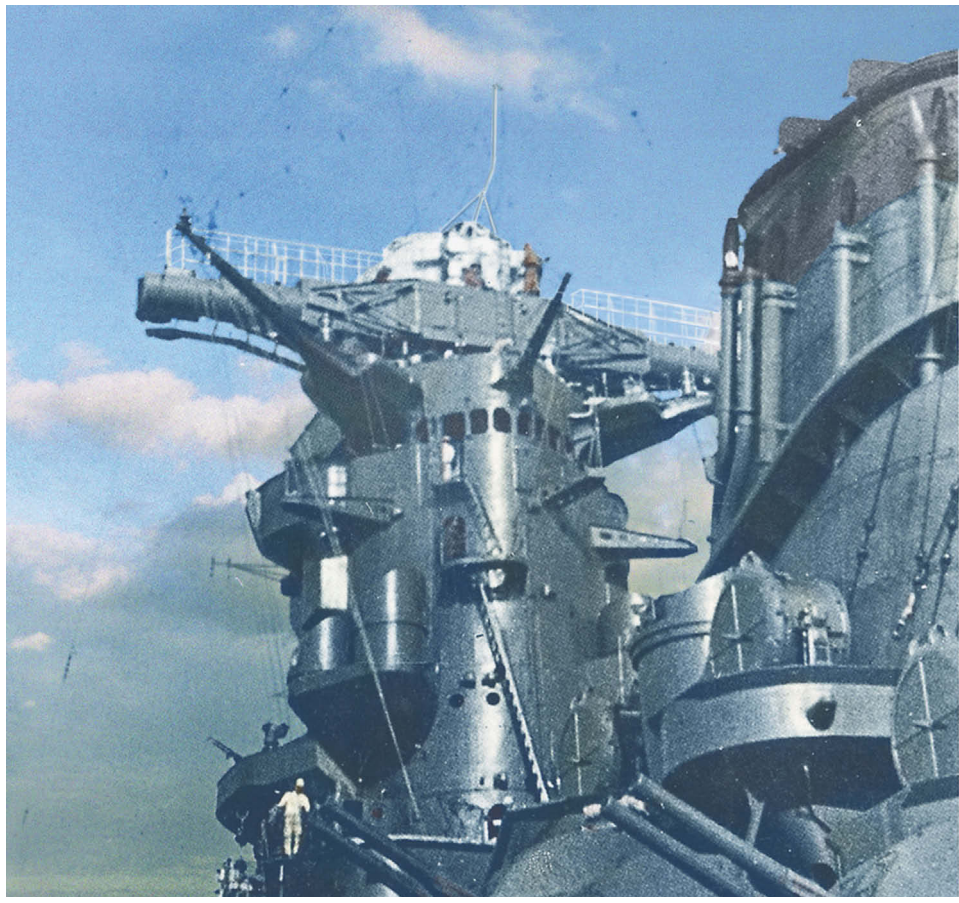
Two twin 13mm machine-gun mounts were installed on both sides of the tower bridge and were similar in construction to the Hotchkiss type, with a horizontal range of 6000m, vertical range of 4500m, rate of fire 450 rounds per minute and ammunition supply of 2500 rounds per gun. In 1944 *Musashi* carried twin rocket launchers each armed with 28 12cm AA common rockets and four depth charge launchers located on both sides on the stern deck.

Fire control system

Main battery

Both battleships were equipped with the Type 98 low angle fire control system – the ultimate in Japanese low angle fire control installation and specially designed for the *Yamato* class battleships. The principal parts of this installation were as follows:

Four 15.5m rangefinders, one on top of the tower bridge and the remaining three in 46cm gun turrets, and one 10m rangefinder on the top of the after tower. The one on top of the tower bridge was a triple rangefinder with one stereoscopic set. Special attention should be paid here to the high quality of Japanese optics and at the same time to the unusual base length of the 15.5m rangefinders which allowed exceptional range estimation and consequently a high degree of accuracy in shooting, usually bracketing the target with early salvoes.



A rear view of Musashi*'s funnel, tower bridge and searchlight platform in September 1942 after fitting Type 21 radar antennas on both arms of the 15.5m rangefinder. Note the white painted 'Hoiban' LA director and antennas – dating from the middle of 1942 to the end of 1943.*

Type 98 low angle 'Hoiban' directors were situated in two completely enclosed towers – one on top of the main 15.5m rangefinder and second on top of the 10m rangefinder. They were manned by a control officer who operated the main telescope searchlight and three others: layer, trainer and cross-leveller. Level and cross-level corrections were handled by a 'match the pointer' system. The director gave train and elevation orders to the guns.

Type 98 'Sokutekiban' was a component of the Japanese fire control system unknown in Western navies. It was a section of the computer and received its information from the directors. It gave target course and target speed information to the computers.

Type 98 'Shagekiban' low angle computer was the latest Japanese fire control table and the first low angle computer with an automatic electrical-mechanical follow-up system.

Type 98 firing device consisted of two components:

1. Trigger time limiting device: limited the time of two or more guns to 0.08–0.2 seconds after the firing circuit was activated.
2. Firing time separator: reduced interference in flight; two guns could not be fired at the same instant.

The battleship's main battery and her fire control system were also adapted for use as anti-aircraft fire.

Secondary guns

15.5cm guns were equipped with an 8m turret rangefinder and a fire control system. This was the same type as used in the main battery system with 4.5m instead of the 15.5m and 10m rangefinders.

12.7cm high angle guns: These were controlled by the Type 94 'Kōsha Sōchi' HA fire control system.

25mm machine-gun batteries: These were controlled by the Type 95 'Shageki Sōchi' short range HA director. It was a simple course and speed system that was not up to Western standards, though all triple 25mm guns had the advantage of remote control.

Sensors

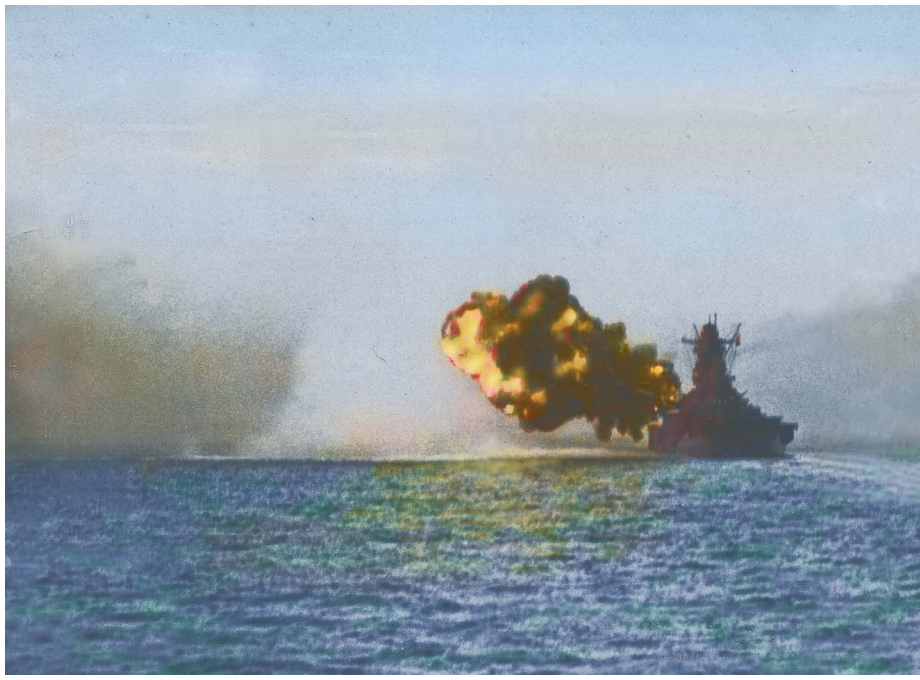
Yamato and *Musashi*, as the most modern and strategically important battleships of the Imperial Japanese Navy, were supplied with the latest radar and electronic equipment.

Type 21

The first radar was installed on *Musashi* in September 1942 and on *Yamato* in July 1943. It was the Type 21 Gō Dentan Kai 3 air and surface search radar. Two Type 7 Gata radar antennas of 'mattress' pattern with combined transmit and receive arrays were installed on both arms of the 15.5 m rangefinder. The Type 21 Kai 3 radar's wave length was 1.5m, power 25–30kW and range 120km (aircraft group), 70km (single aircraft).

Type 22

Surface search/gunnery control radar Type 22 Gō Dentan Kai 4 was installed on *Yamato* in February 1944 and on *Musashi* two months latter in April 1944. The radar antenna comprised two electromagnetic horns – upper for receiving, lower for transmitting. Two Type 22 radars were installed on the sides of the upper part of the tower bridge. The radar was not adapted for fire control. Its characteristics were wave length 10cm, power 2kW, maximum detection range 35 km + – 700m (battleships), 20km (cruisers), 17km (destroyers), bearing error + – 5˚.



The Musashi's *main gun salvo during firing research on the impact of the blast, at Setona-ka in Iyo Nada on 26 July 1942.*

Type 13

The type 13 Gō Dentan air search radar was fitted on *Yamato* and *Musashi* at the same time as the fitting of Type 22 radar. Two ladder-type antennas were located on both sides of the main mast. The characteristics of the radar were a separate set for transmission and receiving, wave length 2.0m, power output 10kW, maximum detection 100km (aircraft group), 50km (single aircraft), range error + – 2–3km, bearing error + – 10˚.

Sonar

Both battleships were equipped with Type '0' sonar arrays that could detect a submarine when the ship was dead in the water or proceeding at low speed.

AIRCRAFT AND CATAPULTS

Yamato and *Musashi* were designed to carry a maximum of seven floatplanes of the Mitsubishi F1M2 Type '0' (allied code 'Pete') and Aichi E13A1 (allied code 'Jake') types. But on both battleships only Mitsubishi F1M2 floatplanes were actually used.

Aircraft were launched into the air by two 19.5m long catapults of Type Kure Shiki 2 G 5 Gata and a 6-ton crane with a 20m long arm was used to lift them out of the water. The floatplanes were stowed in a hangar and before flight were moved across the aircraft deck by a system of trucks and rails to the catapults.

Principal specifications of the Mitsubishi F1M2 two-seat general-purpose floatplane	
Power plant	875hp
Span	11.0m
Length	9.5m
Height	4.0m
Speed (max)	370km/h
Cruising speed	193 km/h
Range max/norm	740km/442km
Weight (max)	2856kg
Ceiling	9440m
Armament	3 x 7.7mm MG + 60kg bombs
Wing area	29.54 m^2

BOATS

Yamato and *Musashi* were designed to carry 16 boats but usually carried 14. All the boats were kept in hangars because of the terrific blast from the main battery. They were lowered and raised by an overhead travelling crane (side hangars) or by a 6-ton aircraft crane (boat hangars on the stern deck – UD). The boats consisted of two 17m ceremonial barges with 150hp drive, one 15m ceremonial barge with 150hp drive, one 11m motorboat with 60hp drive, four 12m motor launches with 30hp drive, four 9m cutters unpowered, one 8m and one 6m sampan (unpowered).

SEARCHLIGHTS

After completion, *Yamato* and *Musashi* each carried eight 150cm director controlled searchlights for night fighting. Their number was reduced to six in 1944 and next to four in 1945 on *Yamato*. AA control positions were installed in their place (on *Musashi,* two rocket launchers). Both battleships also carried four 60cm and two 40cm signalling searchlights.

INTERIOR COMMUNICATIONS

These were based on three principal methods: voice tube (146 installed), telephone (491 installed), pneumatic air chute (14). Each ship carried 40 radio receivers and 17 transmitters, with operating frequencies ranging from low frequency (LF) to very high frequency (VHF). Most of the equipment operated at LF, MF and HF.

The Navy Type 2 infrared communications were developed in 1942.

COMPLEMENT

The crews of *Yamato* and *Musashi* as completed were planned as 2500 officers and men, but during service this number was increased by fitting additional armaments and equipment. In April 1945 the number of crew on *Yamato* was increased to 3332 sailors (from this number only 23 officers and 246 men survived on 7 April 1945).

Japanese sources give *Musashi*'s complement on 24 October as 2399 officers and men, and in comparison to *Yamato* the crew looks very understated. Maybe only the number of lost – 1023 officers and men – was correct.

Additionally, on the last cruises of both battleships squads of maritime regiments were transported, but the starting number and number lost were unknown.

WARTIME COLOUR SCHEMES

1. Gold was used for the 120cm diameter chrysanthemum crest on the bow.

2. The hull colour of the Imperial Japanese Navy ships varied in shade, although it was based on regulation colours. The basic grey (medium grey) was made up according to a Paint Mixture Standard Formula and consisted of 15 per cent black, 75 per cent white, 6 per cent brown, 4 per cent blue. This colour was used for the above-water part of the hull, the superstructures, gun turrets, the topside fittings, metal decks and sides of the boats.

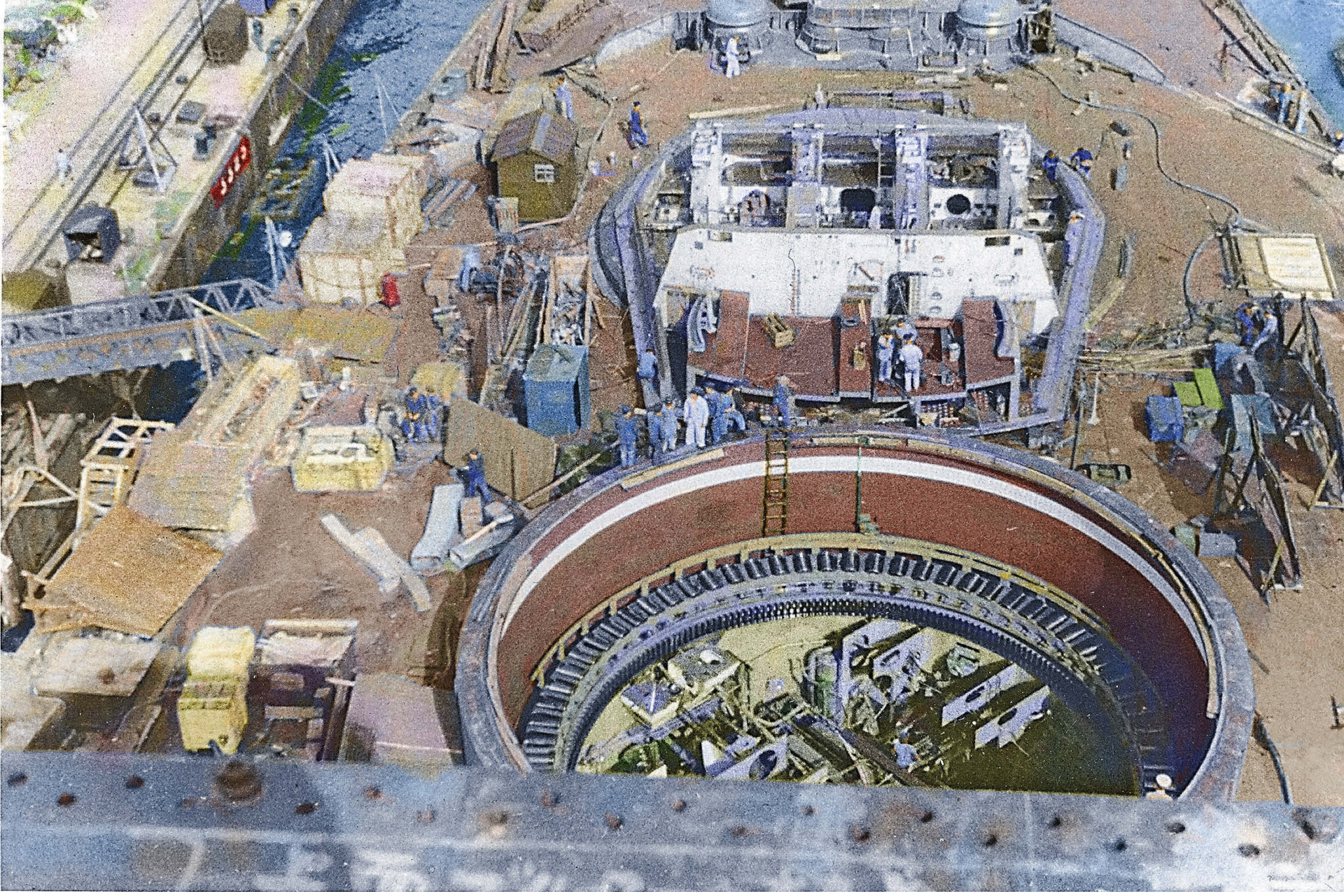
3. A reddish-tinged brown was used on the underwater part of the hull, and consisted of 20 per cent red, 65 per cent brown, 10 per cent black and 5 per cent white.

4. White was used for the azimuth scales of the AA rangefinders, the upper part of the tower bridge – above the 15.5m rangefinder (Hoiban, Type 21 radar antenna) – from the middle of 1942 to the end of 1943, the chrysanthemum on both sides of the funnel in April 1945, the stripes of the circular railings of the open triple 25mm gun mounts, the 200mm high numbers on the base of the deck 25mm MG enclosed mounts, the stripes on the edge of the hull – end of 1944–45 – and the inner surfaces of the rangefinder and gun rangefinder openings.

5. Brown (canvas) was used for the blast bags and the gun muzzle covers.

6. Yellowish-brown (like milk chocolate) was used for the non-slip linoleum strips on the aircraft deck (with 20mm brass strips attaching it to the deck surface.

7. Black was used for the upper part of the funnel and mast.



The forecastle of Yamato *during construction on 3 June 1940, No.1 main armament gunhouse is nearing completion, and on the barbette of No. 2 main turret are vislble rollers with training rack and upper rotating shell stowage and shell and cordite hoists.*

8. The chequered steel plates of the anchor deck were zinc coated not painted and were a light grey colour.

9. The wooden deck (main part of FD) was unpainted 'hinoki' cypress wood in a grey tint with a little brown. The planking was made of 140mm wide planks.

10. Aircraft: Upper surface sea green N-1, lower surface gull grey N-2, orange stripes on wing's leading edge (middle part), white-red stripes on floats. White stripes on tailplanes and number codes on fins. The Hinomaru was red with white borders.

11. Wooden decks and probably roof of turret No.1 of main guns were painted black for the night breakthrough in the San Bernardino Strait. This hastily applied camouflage was mainly based on soot from stacks used on both *Yamato* and *Musashi* (18–24 October 1944).

YAMATO AND *MUSASHI* SUMMARY OF SERVICE

IJN *YAMATO*

The Bureau of Naval Construction's three groups of outstanding naval designers – Fujimoto, Hiraga and Fukada – had drawn up as many as 23 preliminary designs up to March 1937.

March 1937: The final design was drawn up by Dr Hiraga, the leading naval architect of the Imperial Japanese Navy.

4 November: Construction began on 'Battleship No.1' – the keel was laid down in the dry dock of the Kure Kaigun Kōshō shipyard.

September–November 1939: main engines fitted.

May–October: Boilers fitted.

8 August 1940: Launched.

May–July 1941: Main guns fitted.

12 August 1941: Departs Kure for trials.

Admiral Yamamoto (front row, sixth from left) and his staff aboard the Yamato *early in 1942. The photo was taken at the after end of the superstructure on the port side. The rear part of the 15.5cm gun turret (turret No.2) is visible in the left background.*

5 September 1941: Kure – Battleship No.1 is being fitted out.

8 December: The attack on Pearl Harbor; at the opening of hostilities, Battleship No.1 is still fitting out in Kure.

16 December 1941: Battleship No.1 is completed and registered in the Kure Naval District as *Yamato*. She then joined the First Battleship Division part of the Combined Fleet, which consisted of *Nagato* and *Mutsu,* and began intensive training, next stay at anchor at Hashirajima – Inland Sea.

12 February 1942: *Yamato* became the flagship of Admiral Isoroku Yamamoto, Commander-in-Chief of the Combined Fleet.

20-23 February: The Chief of Staff of the Combined Fleet Rear Admiral Ugaki conducts a series of war games aboard *Yamato* to test plans for the second-stage operations.

9 March 1942: Admiral Yamamoto issues orders to the fleet to prepare for Operation 'C', a raid into the Indian Ocean.

March 1942: Inland Sea – trainings and gunnery practice.

April 1942: Captain Arima, the Chief Equipping Officer of *Yamato*'s sister ship *Musashi,* pays an orientation visit with members of *Musashi*'s fitting-out crew.

April–May 1942: Training and gunnery practice.

Early May 1942: Admiral Yamamoto conducts war games aboard *Yamato* to test plans for the invasion of Midway.

23 May 1942: Returns to Hashirajima.

29 May: Operation 'MI' was begun, at 06.00 *Yamato* departed Hashirajima with the First Fleet, serving as Admiral Yamamoto's flagship as the command centre in the battle. It was intended to use her main artillery at Midway. After the defeat and loss of four aircraft carriers she returned to the Inland Sea. The battle once more confirmed the supremacy of aircraft carriers in war. At that time a decision was made to convert the third battleship *Shinano* (then being built) into a heavy aircraft carrier.

10 June 1942: 1200 miles SE of Tokyo an unidentified submarine fires two torpedoes at *Yamato* and both torpedoes miss.

5 August 1942: *Musashi*, her sister ship, entered service and joined the First Battleship Division.

Kure – 20 September 1941 – Yamato *is shown during her final phase of fitting out. The steel mesh supports for the canvas blast bags can be seen above and below the nearest gun barrel, and splinter armoured protection below the gun barrel elevated to its maximum elevation of 45 degrees. The aircraft carrier to starboard is the* Hōshō*, and in the background is the stores ship* Mamiya*.*

August 1942: During operations in the Solomon Islands, *Yamato* went to Truk Island to support a series of operations to recapture Guadalcanal Island, but did not take part in the campaign.

28 August 1942: *Yamato* was attacked by the submarine USS *Flying Fish,* and next arrived in Truk where she served there as headquarters and flagship of the Combined Fleet.

9 September 1942: The Combined Fleet main units were transfered to a new anchorage south of Summer Island.

17 October 1942: Truk – oiler *Kenyō Maru* arrived empty, and *Yamato* and *Mutsu* each transferred 4,500 tons of fuel oil to her to refuel IJN warships that were involved in the Guadalcanal operations.

1 November 1942: Aboard *Yamato* was a festive dinner to celebrate the victory at the battle of Santa Cruz.

22 January 1943: *Musashi* arrived at Truk to join *Yamato.*

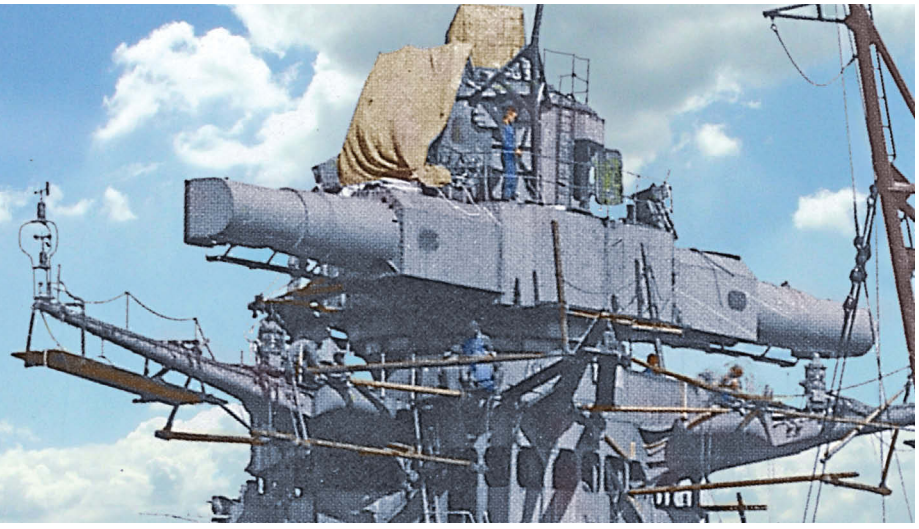
11 February 1943: *Musashi* became the flagship of Admiral Yamamoto. In the meantime the situation around the Solomon Islands went from bad to worse. The Japanese had to abandon Guadalcanal.

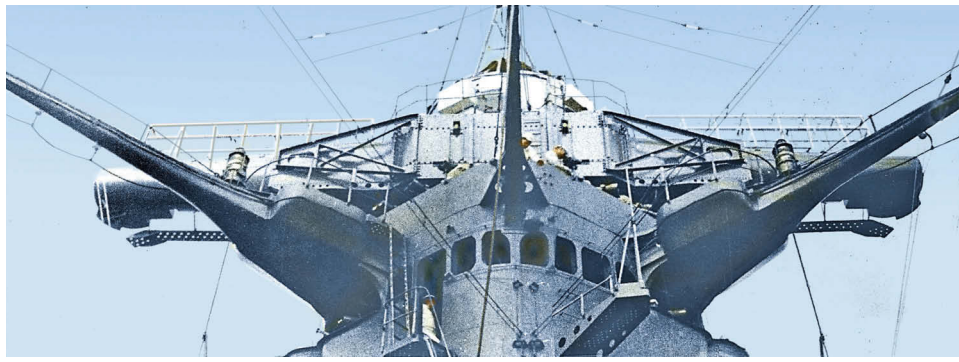
18 April 1943: Admiral Isoroku Yamamoto was killed (his aircraft was shot down over Bougainville Island) and *Musashi* became the new flagship of Admiral Mineichi Koga, successor to Admiral Yamamoto.

8 May 1943: Sailed from Truk to Yokosuka.

13 May 1943: Departs Yokosuka for Kure.

The upper part of Yamato*'s tower bridge with 15.5m rangefinder, Type 98 LA Director 'Hoiban', with its periscope tower covered by canvas, and signal yards with wind indicators fitted.*





Close-up of the top of Musashi*'s tower bridge and main rangefinder from aft. The lattice structure on the rear wall of the rangefinder may have been strengthening to carry the weight and wind resistance of the radar aerials. On the signal yards are visible platforms for 60cm searchlights, and 2kW daylight signal lanterns.*

21–30 May 1943: Drydocked for inspection and repairs.

12 July 1943: *Yamato* drydocked at Kure and was equipped with Type 21 Mod 3 radar. Twelve 25mm MG (4 x 3) were fitted on the forecastle deck before and aft 15.5cm side gun mounts (turret No.3 and 4), and 15.5cm guns were provided with coaming armour and their barbettes with 28mm thick additional armour. *Yamato*'s fuel storage was reduced and her main and auxiliary rudder controls were improved.

16 July 1943: Yamato was visited by the German naval attaché to Tokyo Konteradmiral Paul Wenker, (a former Commanding Officer of the pocket battleship *Deutschland/Lützow*). He was not able to see or understand the real calibre of the main turrets during a one-hour visit on *Yamato*. He described the main gun calibre as 40cm. Permission to visit *Yamato* was given in response to a special request made by Adolf Hitler and Admiral Karl Dönitz in reciprocation of Admiral Naokuni Nomura's visit aboard the battleship *Tirpitz* in March 1941.

16 August 1943: *Yamato*, loaded with troops and supplies, departs Kure with *Fusō*, *Nagato* and Destroyer Divisions 16's *Amatsukaze* and *Hatsukaze* next stops at Yashima anchorage.

17 August 1943: *Yamato* departed Yashima via Yokosuka for Truk in task group: *Fusō, Nagato*, carrier *Taiyō*, 4' squadron *Atago* and *Takao* and destroyers *Akigumo, Yūgomo, Ushio, Amatsukaze* and *Hatsukaze*.

23 August 1943: The task group arrived at Truk.

17 October 1943: *Yamato*, *Musashi*, *Nagato, Fusō, Kongō, Haruna* with three aircraft carriers, seven heavy cruisers and three light cruisers and destroyers, left Truk to face US forces which were planning a raid on Wake Island.

19–23 October 1943: Japanese forces arrived at Brown Atoll, Eniwetok

26 October 1943: Forces returned to Truk after no contact with enemy forces.

17 December 1943: arrived at Yokosuka.

25 December 1943: *Yamato* was hit by a torpedo fired by the US submarine USS *Skate* near Truk. The torpedo hit her starboard hull near No.3 Main turret (frame 165) with the result that about 3000 tons of water flooded into the upper powder magazine through the small hole in the side armour joint. She arrived in Truk that day for emergency repair.

10 January 1944: Departed Truk for Kure with three destroyers.

16 January 1944: *Yamato* arrived in Japan and was drydocked at Kure for necessary repairs and modifications to the bracket structures of her armour. At the same time her anti-aircraft armament was modernised. In place of two 15.5cm broadside turrets, which were removed, six twin 12.7cm closed turrets were reinstalled. In place of six 12.7cm closed turrets were fitted six new open mounts with 12.7cm guns. Twelve triple and twenty-six single 25mm MG were mounted on her weather deck. Type 22 and Type 13 radar were installed and the construction of the main mast was changed. Two 150cm searchlights were removed and later installed ashore at Kure. Repairs and modernisation lasted until 18 March, when she was undocked.

31 March 1944: Admiral Koga was killed and the new Combined Fleet Commander, Admiral Soemu Toyoda, was appointed.

11 April 1944: *Yamato* departed Kure for trials in the Iyo Nada and returned to Hashirajima that evening.

17 April 1944: Returned to Kure to load supplies.

Details from front of the port-side 15.5m rangefinder arm with the Type 21 (21 Gō) radar mattress type antenna fitted firstly on Musashi *in September 1942 (on* Yamato *eight months later).*

The division between the wooden deck and the steel aircraft deck is clearly visible in this view of Musashi *from July 1942. Note the twin 12.7cm HA gun mount in the foreground and the canvas-covered 150cm searchlight.*

A Mitsubishi F1M2 floatplane aboard Musashi *seen from under the aircraft crane, January 1944. The new type MG control tower can be seen on the left, and in the right foreground the sisal rope curtain that closed off the boat stowage.*

24 June 1943. An Imperial visit to Musashi *anchored in Yokosuka. In the centre sitting is Emperor Hirohito with his brother Prince Takamatsu and Admiral Koga.*

21 April 1944: Departed Kure for Okinoshima, loaded troops.

22 April 1944: Departed Okinoshima with cruiser *Maya* and destroyers *Shimakaze, Yukikaze* and two other destroyers.

28 April 1944: Arrived at Manila, unloated troops and supplies, then departed.

1 May 1944: Arrived at Lingga near Singapore.

3 May 1944: At Lingga she was designated the flagship of Vice Admiral Ugaki.

11 May 1944: Sailed with Vice Admiral Jisaburō Ozawa's Mobile Fleet from Lingga to Tawi Tawi.

14 May 1944: Anchored at Tawi Tawi.

May–June 1944: At Tawi Tawi anchorage – *Yamato* and *Musashi* participated in joint gunnery exercises at ranges of almost 22 miles. At that time the Combined Fleet was reorganised – the main part of the Fleet became a carrier striking force and the battleship group, including *Yamato* and *Musashi,* formed the support force for the aircraft carriers. The Commander-in-Chief of the Combined Fleet hoisted his flag on the light cruiser *Ōyodo*. When the US forces landed on Biak Island, West New Guinea, towards the end of May 1944, the Imperial Japanese Navy decided to use two 46cm gun battleships to attack the enemy invasion force.

7 June 1944: Bongao, Tawi Tawi – *Yamato* received fresh provisions from the supply ship *Kitakami Maru.*

10 June 1944: Operation 'KON' – the relief of Biak. *Yamato* with *Musashi* and *Noshiro* and two destroyers departs Tawi Tawi for Batjan. The operation was not realised and both battleships were recalled on their way because of the imminent US invasion of Saipan Island. After the Mariana sea battle (A Operation, the twin battleships taking part in the battle as part of Admiral Kurita's vanguard group) they arrived on 22 June at Okinawa and 24 June at Hashirajima, going on 29 June to Kure to prepare for the next operation, the defence of the Philippines.

29 June–8 July 1944: Five additional triple 25mm MGs were installed on *Yamato*, making twenty-nine triple and twenty-six single 25mm MG at 113 barrels.

9 July 1944: Both battleships left Japan and, via Okinawa, hurried south to the Lingga anchorage.

16 July: Arrived at Lingga anchorage and underwent training. The surface force remained in the vicinity for three months conducting training and was immediately alerted.

18 October 1944: Black deck camouflage, intended for the night breakthrough in the San Bernardino Strait, is hastily applied to *Yamato* and *Musashi*. The main component was soot from the ships' funnels. On this day the battleships left the Lingga anchorage.

22 October 1944: Arrived at Brunei. After refuelling *Yamato* and *Musashi* left to make a daring dash eastward through the Philippines to launch an attack on the enemy in Leyte Gulf.

23 October 1944: In the early morning, when the surface force was passing northeast along Palawan Island, two heavy cruisers – *Atago*, the flagship of Admiral Takeo Kurita, and *Maya* – were sunk by submarine torpedoes from USS *Darter* and USS *Dace*. Admiral Kurita hoisted his flag on *Yamato*.

24 October 1944: *Musashi*'s war career ended on the Sibuyan Sea. As result of air attacks she was hit by a minimum of twenty torpedoes and seventeen bombs and had more than fifteen near misses. And four-and-a-half hours after the last attack the battleship went down with 1039 officers and men.

Yamato was hit by three 1000lb AP bombs during the attack. The first bomb penetrated the anchor deck and demolished the port chain locker and exploded below the waterline. Two other bombs hit turret No.1's 46cm guns and the next penetrated the FD deck to the crew's quarters. These did little damage and she was easily repaired.

25 October 1944: *Yamato* broke through the San Bernardino Strait to the east of the island chain. In the Battle of Samar Gulf *Yamato*'s 46cm guns opened fire on the US escort carriers and destroyers. It was the first and the last of her battles with enemy ships. She fired a total of 104 rounds of 46cm projectiles, as a result of which one escort carrier and