

Peace-time attrition expectations for naval fleets

An analysis of post-WWII maritime incidents

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Abstract

This report presents a database of service life-threatening accidents/incidents involving the fighting ships from five navies—Canada, United Kingdom, United States, Australia, and New Zealand—since the end of the Second World War. The research identified 1,222 ships in these navies, including aircraft carriers, cruisers, destroyers, frigates, submarines, littoral ships, and replenishment oilers, which have delivered (to May 2017) a combined 28,985 years of service. The accidents/incidents research employed only open literature sources and identified 1,254 incidents. Each was categorized (a taxonomy of 17 incident types was employed), and the service time lost due to the incident was either calculated from established facts or estimated by the author based on known comparable incidents. The report also presents a summary analysis of the peacetime-only incidents, including a breakdown by incident type, ship category, and decade of occurrence. The full database is appended to the report in digital form. The intent of this research is to provide maritime force structure planners with data for statistical underpinnings in support of fleet sizing decisions.

Significance to defence and security

Data gathered on historical ship incidents and losses can be utilized to determine if scalable distributions and relationships exist between military asset/platform classes for whole life expectancy, factoring in life span, mid-life refits, accidents, combat attrition (including terrorist-style attacks), and end-of life “maintenance” periods. Such relationships will help the Royal Canadian Navy determine requirements for future force structure sizes when accounting for all such factors that can render the fleet size variable.

Résumé

Le présent rapport consiste en une description d'une base de données sur des accidents/incidents arrivés en service et mettant des vies en danger qui impliquaient des navires de combat de cinq marines—Canada, Royaume-Uni, États-Unis, Australie et Nouvelle-Zélande—depuis la fin de la Deuxième Guerre mondiale. La recherche couvre 1 222 navires de ces marines, y compris des porte-avions, des croiseurs, des destroyers, des frégates, des sous-marins, des navires côtiers et des ravitailleurs, qui comptent au total (en date de mai 2017) 28 985 années de service. La recherche sur les accidents/incidents n'a porté que sur des sources documentaires ouvertes et a permis de relever 1 254 incidents. L'auteur a catégorisé chacun d'entre eux (au moyen d'une taxonomie de 17 types d'incidents), puis a calculé le temps de service perdu en raison de l'incident à partir de faits établis ou d'estimations faites par l'auteur en fonction d'incidents comparables connus. Le rapport présente une analyse sommaire des incidents de temps de paix seulement, y compris une ventilation par type d'incident, par catégorie de navire et par la décennie où l'incident s'est produit. La base de données complète est jointe au rapport sous forme numérique. La recherche a pour but de fournir aux planificateurs des structures des forces maritimes des données avec lesquelles étayer leurs décisions en matière de taille de la flotte.

Importance pour la défense et la sécurité

Les données historiques recueillies sur les incidents et les pertes impliquant des navires peuvent servir à déterminer si des relations échelonnables existent entre les ressources militaires/les classes de plateformes pour toute leur durée de vie prévue, compte tenu de la durée de vie, des carénages de mi-vie, des accidents, de l'attrition due au combat (y compris les attaques de type terroriste) et les périodes de « maintenance » de fin de vie. De telles relations aideront la Marine royale canadienne à déterminer les besoins relatifs à la taille des futures structures des forces en tenant compte de l'ensemble des facteurs pouvant rendre la taille de la flotte variable.

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1 Introduction

Navies of the world engage in a continuous cycle of acquisition, employment, and disposal of fleets of vessels to support the maritime defence and force projection of their nations. There is usually a planned life for any fleet (typically 20–50 years), but events may arise that reduce the availability of the vessels in that fleet for employment on national defence missions during that period. This analysis hopes to quantify this expected reduction in availability, providing the Department of National Defence (DND), and indeed the defence departments of all nations, with a stronger basis on which to base force structure and fleet sizing decisions.

Air forces fully expect to lose aircraft over time, so the initial acquisition of additional aircraft will be a logical consideration to compensate for such expected future losses. But for navies, most people have a sense that, in peacetime, not a lot of ships are lost to incidents that might arise in the day-to-day operations of a navy. There are a few past incidents that come to quickly to mind, such as Her Majesty's Canadian Ship (HMCS) CHICOUTIMI flooding and electrical fire while on delivery from the United Kingdom (UK) in 2004, or the loss of the nuclear submarines United States Ship (USS) THRESHER and USS SCORPION in the 1960s, or the terrorist attack on the USS COLE in 2000, but these do seem to be rare.

How likely are such incidents? How much lost time can they cause? Is this sufficient to warrant the initial acquisition of additional platforms? This study investigates and attempts to provide some initial answers these questions.

2 Aim and scope

2.1 Aim

This aim of this analysis is to quantify the expectations for peacetime attrition in modern naval fleets. Maritime aircraft are excluded from this study.

2.2 Scope

The best (and, really, the only) predictor we have of future attrition are historical rates. The applicability of the data will depend on the operational context, the expected trends over time in terms of types of missions that will occur, and significant technological shifts that may impact ship survivability and reparability. However, a place to start based on solid quantitative research is better than none at all. So the approach adopted here is to identify past maritime incidents that have impacted the availability of naval vessels, and provide a summary analysis of that data.

How far back in time should one go? Arguably, the best data is the most recent. Future fleets will have the technology and will be operated in ways that are evolutions from the recent past. The farther back in time one goes, the less comparable the ships and their operational contexts will be. The decision was taken for this study to examine the period from the end of World War II (WWII) to the present. Study resources were finite, as well, placing a practical limit on the research time window. Generally, only ships that were commissioned after 1945 were considered in this study, although a few exceptions of key war-era ships (primarily aircraft carriers and battleships) that served well into the 1970s were included.

Which of the world's Navies should be examined? While it would have been nice to examine the operational histories of every ship of every Navy in the world since WWII, study resources and data availability made this impractical, if not impossible. Unclassified data was located for the 'five-eyes' nations of Canada, Australia, New Zealand, the United Kingdom, and the United States (US). The operational histories of 1,222 navy ships across these five nations were researched and incident lists compiled. The author believes that this database is sufficiently representative and of high enough quality to be employed in the prediction of future attrition for the Royal Canadian Navy (RCN).

Which classes of ships should be included? The major capital vessels (the 'fighting ships') of a Navy must be considered. This includes aircraft carriers, destroyers, frigates, submarines (conventional and nuclear), and major amphibious platforms. Also considered were the significant gunboats of earlier decades, such as battleships and cruisers, which were active in this time window. Replenishment oilers, while often considered as civilian-pattern support ships, were also included in this analysis because they are critical to world-wide naval force employment (although time did not permit the United States oilers to be researched). For the RCN, lesser ships such as the current minesweeper fleet, hydrofoils, etc. were also examined and included.

What types of incidents/accidents/mishaps should be considered? The intent was to include any event that could threaten the service life of the vessel. Such 'service-life-threatening' (SLT) events are those that place the ship at risk of damage and/or crew injury, and have the potential to

render the ship unavailable for employment for a period of time. Combat incidents¹ were included for the sake of completeness. A number of ships were shelled by shore batteries during the Korean and Vietnam Wars, and the Falklands War and Gulf Wars saw missile or mine attacks. These combat incidents were included in the database, but were excluded from the subsequent analysis of peacetime attrition.

This study did not capture incidents where equipment had simply failed, but no threat to the viability and integrity of the ship and its crew resulted. The ship may have been unavailable for a time undergoing repairs, but these failures were considered routine and to be expected, and were not captured in this study. However, if the failure rendered the ship vulnerable to SLT damage, for example it lost all propulsion in heavy seas, then that incident was captured.

The incident classification taxonomy that was employed in this study included the 17 terms listed below. They are considered to be non-overlapping, in the sense that each incident will receive one and only one assigned category, which will be the primary action that was deemed by the author to be the most responsible for the incident. For example, if an aircraft crashes onto the flight deck of a ship and the leaking fuel causes a fire, it will be labelled an 'Aircraft crash' incident, and not a 'Fire'.

- *Collision*. Any time two ships collide there is the prospect of grave damage, even sinking. This was the most common class of incident, partly due to some double-counting that arises when both boats happen to be part of this database.
- *Grounding*. This term is broader than just ships running aground. It included any contact with a hard object, be it the sea bed, a pier, or floating ice. A substantial number of berthing incidents were captured under this term.
- *Explosion*. This category captured explosions from any source, such as boilers, engine rooms, ammunition storage areas, etc. The only exclusions were explosions caused by attacking weapons (captured under the 'Attacked' or 'Terrorism' categories) or from the operation of onboard weapons (classified as 'Weapon incident').
- *Fire*. Fire is never a minor problem aboard ship. The close proximity of key spaces and the presence of fuel and ammunition all magnify the threat of fire.
- *Mechanical*. This captured any mechanical failure that places the ship and its crew in jeopardy of SLT damage or injury.
- *Flooding*. Water will naturally ingress from any fault below the waterline, and is always a serious threat onboard any naval vessel.
- *Aircraft crash*. This is a special risk that aircraft-carrying vessels are exposed to. Usually the aircraft suffers much more damage and injury than the ship from which it is operating, but the threat of SLT damage to the ship is very real. Note that incidents where aircraft flying off a ship crash into the sea away from the mother ship are not captured in this study.
- *Weather*. Weather conditions can be so severe that they challenge the physical integrity of the vessel itself.

¹ The 'Cod Wars' between the UK and Iceland in the early 1970's over fishing rights off Iceland are considered peacetime operations and not 'combat' operations, as weapons were not engaged. These 'wars' might be more accurately described as 'floating demolition derbies.'

- *Weapon incident.* The handling, maintenance, and operation of onboard weapons can be the source of serious accidents.
- *Nuclear incident.* This was intended to capture any situation where something went wrong with a nuclear power plant or a nuclear weapon onboard the vessel.
- *Fouling.* This category mostly applied to submarines that snag the cables of towed ships or the nets of fishing boats. Sadly, it is the fishing boats and not the submarines that usually fare the worst.
- *Terrorism.* The USS COLE attack while in port in Yemen in 2000 is the notable incident in this category.
- *Sabotage.* Sailors or shipyard maintenance workers have been known to sabotage components of ships, enough so to warrant a special category here.
- *Protest action.* It happens, but not very often. While the ship itself is seldom at any severe risk, this category captured it.
- *Attacked.* This category allowed for separation of the non-peacetime incidents.
- *Unknown.* The cause of the event simply was not identified. This category was assigned to just 2 situations—the loss of the submarines HMS AFFRAY in 1951 and USS SCORPION in 1968.
- *Miscellaneous.* If none of the above 16 categories applied, then this one did.

What data sources were employed? Quite honestly, the best source of incident data is the internet. Some of the standard references such as *Janes Fighting Ships* [1] have extensive information on the capabilities of the naval platforms and onboard systems, but very little in the way of operational history. Books like *Ships of the Royal Navy* [2] are good for identifying some basic facts as well, but the online sources proved to be the most useful. The main five are listed below:

- *Wikipedia* [1]. Virtually every one of the 1,222 ships identified for this study has a dedicated web page on Wikipedia.
- *Greenpeace's online paper on Naval Accidents 1945–1988* [4]. A thorough compilation of worldwide accidents, with short statements summarizing each and identifying the vessels involved.
- *Navysite.de* [5]. To quote the developers, their site, while having no official connection to the US Navy, is “the largest European US Navy website. The whole project was started in early 1999 by two German students and has since then developed into an interesting and informative source of US Navy related information.”
- *USCarriers.net* [6]. USS histories and deployments, with very detailed chronologies of deployments for those ships covered. Focuses more on current and recently decommissioned ships.
- *For Posterity's Sake* [7]. A Royal Canadian Navy Historical Project, with valuable details on RCN ships.

The three categories of submarines make an interesting comparison. Strategic submarines live a relatively gentle operational life in comparison to their tactical sisters. They too represent a higher capital investment, so one might not be surprised to see that their average life of 26.8 years is higher than the 25.1 and 24.6 values associated with conventional and nuclear attack submarines, respectively.

Destroyers lead the surface combatants in average life at 26.3 years, followed well back by cruisers and frigates at 22.5 and 21.6 years, respectively. The (traditionally) heavily armed cruisers and the (generally) smaller frigates seem to get replaced more quickly.

Replenishment oilers hit right near the overall average at 25.1 years. The 'others' category comprises a collection of 'one-off' experimental vessels (new propulsion, hybrid roles, etc.), so the observed short average life is no surprise.

Which individual ships served the longest? It is always interesting to see extremes. The list of ships in the database that exceeded 40 years of service life is presented in Table 12. A total of 26 ships achieved this level.

Note that the service life values in this database do not include any follow-on life with navies outside of the five considered here. Many of these ships were sold on to other navies around the world and continued serving to ages well into their 50s and 60s.

Note that seven of the ships listed in Table 12 are still serving as of May 31, 2017.

USN aircraft carriers top the list, headed by USS ENTERPRISE at 55.2 years. The list includes 7 carriers, all 4 battleships, and 1 littoral vessel of the US Navy. The table also lists five Royal Canadian Navy ships (2 replenishment oilers and 3 destroyers), including HMCS ATHABASKAN, which is still active but soon to be retired. The list also includes two Royal Navy replenishment oilers.

3 The incident database

This research identified 1,222 vessels that have served 28,985 total years of service for the Navies of Canada, Australia, New Zealand, the United Kingdom, and the United States since the end of WWII. The incident research identified 1,254 incidents/accidents that caused (or reasonably could have caused) service-life-threatening (SLT) damage and/or casualties. Thus, over the lifetime of a capital warship, one can expect an average of about one such mishap to occur.

3.1 Incident summaries by ship class

Tables 1 through 5 present the incident summaries (peacetime and non-peacetime), by ship class, for the Canadian, Australian, New Zealand, United Kingdom, and United States Navies, respectively. The average class life value (in years) is shaded grey if there are ships in the class still serving.

Table 1: Incident summary for Royal Canadian Navy ship classes.

Nat.	Ship Class	Type	No.	Lead Ship			Class Avg Yrs	# Incid	Mo. Lost
				Name	ID #	Commis.			
							(active)		
Can	Colossus	Aircraft Carrier	1	Warrior	R 31	14-Mar-46	2.0	0	0
Can	Majestic	Aircraft Carrier	2	Magnificent	CVL 21	21-Mar-48	11.3	5	7
Can	St. Laurent	Destroyer Helo Esc	7	St. Laurent	DDH 205	29-Oct-55	32.7	12	214
Can	Restigouche	Destroyer Escort	7	Restigouche	DDE 257	07-Jun-58	28.2	5	19
Can	Balao	Submarine	1	Grilse	SS 71	11-May-61	8.4	0	0
Can	Mackenzie	Destroyer Escort	4	Mackenzie	DDE 261	06-Oct-62	30.7	2	2
Can	Provider	Replenishment Oiler	1	Provider	AOR 508	28-Sep-63	34.7	0	0
Can	Annapolis	Destroyer	2	Annapolis	DDH 265	19-Dec-64	33.0	2	5
Can	Oberon-Can	Submarine	3	Ojibwa	S 72	23-Sep-65	32.0	1	3
Can	Bras d'Or	Hydrofoil	1	Bras d'Or	FHE 400	23-Jul-68	3.3	1	21
Can	Tench	Submarine	1	Rainbow	SS 75	02-Dec-68	6.1	1	1
Can	Protecteur	Replenishment Oiler	2	Protecteur	AOR 509	30-Aug-69	46.0	4	38
Can	Iroquois	Guid Msl Destroyer	4	Iroquois	DDH 280	29-Jul-72	40.3	7	61
Can	Halifax	Guid Msl Frigate	12	Halifax	FFH 330	29-Jun-92	22.4	9	13
Can	Kingston	Minesweeper	12	Kingston	MM 700	21-Sep-96	19.1	0	0
Can	Victoria	Submarine	4	Victoria	SSK 876	02-Dec-00	11.3	5	175

Table 2: Incident summary for Royal Australian Navy ship classes.

Nat.	Ship Class	Type	No.	Lead Ship			Class Avg Yrs	# Incid	Mo. Lost
				Name	ID #	Commis.			
							(active)		
Aus	Majestic-Aus	Aircraft Carrier	2	Sydney	R 17	16-Dec-48	25.7	12	18
Aus	Daring-Aus	Destroyer	4	Duchess	D 154	23-Oct-52	20.0	7	215
Aus	Tide-Aus	Replenishment Oiler	1	Supply	AO 195	28-May-55	30.6	0	0
Aus	River	Destroyer Escort	6	Yarra	DE 45	27-Jul-61	27.9	3	1
Aus	Perth	Destroyer	3	Perth	D 38	17-Jul-65	34.2	7	13
Aus	Oberon-Aus	Submarine	6	Oxley	S 57	21-Mar-67	24.7	7	8
Aus	Leaf	Replenishment Oiler	1	Westralia	O 195	08-Jun-79	27.3	1	24
Aus	Adelaide	Guid Msl Frigate	6	Adelaide	FFG 1	15-Nov-80	27.6	1	1
Aus	Durance	Replenishment Oiler	1	Success	OR 304	23-Apr-86	30.9	0	0
Aus	Anzac	Frigate	8	Anzac	FFH 150	18-May-96	14.8	1	3
Aus	Collins	Submarine	6	Collins	SSG 73	27-Jul-96	17.3	6	34
Aus	Sirius	Replenishment Oiler	1	Sirius	O 266	16-Sep-06	10.5	0	0
Aus	Bay-Aus	Landing ship dock	1	Choules	L 100	28-Nov-06	10.3	1	2
Aus	Canberra	Landing Helo Dock	2	Canberra	L 2	28-Nov-14	1.8	0	0

Table 3: Incident summary for Royal New Zealand Navy ship classes.

Nat.	Ship Class	Type	No.	Lead Ship			Class Avg Yrs	# Incid	Mo. Lost
				Name	ID #	Commis.			
							(active)		
NZ	Dido	Light Cruiser	3	Bellona	C 63	17-Apr-46	11.6	4	8
NZ	Loch	Frigate	6	Tutira	F 420	19-Apr-49	10.1	3	50
NZ	Bathurst	Corvette	4	Inverell	M 233	10-Apr-52	20.0	0	0
NZ	Whitby-NZ	Frigate	1	Blackpool	F 77	14-Aug-58	12.9	1	1
NZ	Rothsay-NZ	Frigate	2	Otago	F 111	22-Jun-60	22.3	0	0
NZ	Leander-NZ	Frigate	4	Waikato	F 55	01-Sep-66	31.7	2	4
NZ	Endeavour	Replenishment Oiler	1	Endeavour	A 11	08-Apr-88	29.0	0	0
NZ	Anzac-NZ	Frigate	2	Te Kaha	F 77	22-Jul-97	18.5	3	3
NZ	Canterbury	Multi-Role Vessel	1	Canterbury	L 421	12-Jun-07	9.8	1	2

Table 4: Incident summary for Royal Navy ship classes.

Nat.	Ship Class	Type	No.	Lead Ship			Class Avg Yrs	# Incid	Mo. Lost
				Name	ID #	Commis.			
							(active)		
UK	Amphion	Submarine	16	Amphion	S 43	27-Mar-45	23.4	7	252
UK	Olna	Replenishment Oiler	1	Olna	A 216	27-Apr-45	21.6	0	0
UK	Weapons	Destroyer	4	Crossbow	D 96	04-Mar-48	15.1	4	18
UK	Audacious	Aircraft Carrier	2	Eagle	R 5	05-Oct-51	22.1	3	3
UK	Daring	Destroyer	7	Daring	D 5	08-Mar-52	16.9	5	13
UK	Centaur	Aircraft Carrier	4	Centaur	R 6	01-Sep-53	20.5	7	66
UK	Tide	Replenishment Oiler	5	Tidereach	A 96	30-Aug-55	22.2	0	0
UK	Blackwood	Frigate	12	Blackwood	F 78	22-Aug-57	20.9	1	2
UK	Whitby	Frigate	5	Whitby	F 36	11-Jul-56	20.9	1	24
UK	Porpoise	Submarine	8	Porpoise	S 1	17-Apr-58	23.2	11	13
UK	Salisbury	Frigate	4	Salisbury	F 32	27-Feb-57	23.1	5	15
UK	Leopard	Frigate	4	Leopard	F 14	30-Sep-58	19.0	2	3
UK	Leop/Salisbu	Frigate	1	Mermaid	F 76	16-May-73	3.9	1	3
UK	Tiger	Cruiser	3	Tiger	C 20	18-Mar-59	16.8	2	1
UK	Rothestay	Frigate	9	Rothestay	F 107	23-Apr-60	24.1	12	56
UK	Oberon	Submarine	13	Oberon	S 9	24-Feb-61	27.5	5	7
UK	Tribal	Frigate	7	Ashanti	F 117	23-Nov-61	20.4	8	18
UK	County	Guid Msl Destroyer	8	Devonshire	D 2	15-Nov-62	16.2	5	32
UK	Leander	Frigate	24	Leander	F 109	27-Mar-63	23.2	25	98
UK	Dreadnought	Nuc-Pow Submarine	1	Dreadnought	S 101	17-Apr-63	17.2	0	0
UK	OI	Replenishment Oiler	3	Olwen	A 122	21-Jun-65	32.3	0	0
UK	Fearless	Amphibious Assault	2	Fearless	L 10	25-Nov-65	34.4	1	2
UK	Valiant	Nuc-Pow Submarine	2	Valiant	S 102	18-Jul-66	26.1	3	7
UK	Dale	Replenishment Oiler	3	Dewdale	A 129	01-Jul-67	6.7	1	67
UK	Resolution	Ball Msl Submarine	4	Resolution	S 22	02-Oct-67	26.3	4	8
UK	Churchill	Nuc-Pow Submarine	3	Churchill	S 46	15-Jul-70	19.9	1	1
UK	Type 82	Destroyer	1	Bristol	D 23	31-Mar-73	18.2	2	6
UK	Swiftsure	Nuc-Pow Submarine	6	Swiftsure	S 126	17-Apr-73	27.6	7	56
UK	Rover	Replenishment Oiler	2	Gold Rover	A 271	22-Mar-74	42.8	1	1
UK	Type 21	Frigate	8	Amazon	F 169	11-May-74	14.6	6	311
UK	Type 42	Guid Msl Destroyer	14	Sheffield	D 80	16-Feb-75	24.0	10	564
UK	Fort Rosalie	Replenishment Oiler	2	Fort Rosalie	A 385	06-Apr-78	38.4	0	0
UK	Type 22	Frigate	14	Broadsword	F 88	03-May-79	16.6	5	15
UK	Invincible	Aircraft Carrier	3	Invincible	R 5	11-Jul-80	27.5	1	4
UK	Trafalgar	Nuc-Pow Submarine	7	Trafalgar	S 107	23-May-83	27.7	11	33
UK	Type 23	Frigate	16	Norfolk	F 230	01-Jun-90	19.8	3	5

Table 4 (continued): Incident summary for Royal Navy ship classes.

Nat.	Ship Class	Type	No.	Lead Ship			Class Avg Yrs	# Incid	Mo. Lost
				Name	ID #	Commis.			
							(active)		
UK	Fort II	Replenishment Oiler	2	Fort George	A 388	16-Jul-93	20.3	1	24
UK	Vanguard	Ball Msl Submarine	4	Vanguard	S 28	14-Aug-93	20.9	5	8
UK	Ocean	Amphibious Assault	1	Ocean	L 12	30-Sep-98	18.5	0	0
UK	Wave	Replenishment Oiler	2	Wave Knight	A 389	08-Apr-03	13.9	0	0
UK	Albion	Amphibious Assault	2	Albion	L 14	19-Jun-03	13.0	0	0
UK	Bay	Landing ship dock	3	Mounts Bay	L 3008	13-Jul-06	10.1	0	0
UK	Type 45	Guid Msl Destroyer	6	Daring	D 32	23-Jul-09	5.5	0	0
UK	Astute	Nuc-Pow Submarine	3	Astute	S 119	27-Aug-10	3.9	3	9

Table 5: Incident summary for United States Navy ship classes.

Nat.	Ship Class	Type	No.	Lead Ship			Class Avg Yrs	# Incid	Mo. Lost
				Name	ID #	Commis.			
							(active)		
US	Essex	Aircraft Carrier	22	Essex	CV 9	31-Dec-42	25.2	68	112
US	Iowa	Battleship	4	Iowa	BB 61	22-Feb-43	47.6	8	28
US	Baltimore	Heavy Cruiser	10	Baltimore	CA 68	15-Apr-43	14.5	9	17
US	Boston	Guid Msl Cruiser	2	Boston	CAG 1	30-Jun-43	26.6	2	4
US	Gearing	Destroyer	98	Gearing	DD 710	03-May-45	29.7	113	287
US	Providence	Guid Msl Cruiser	3	Providence	CLG 6	15-May-45	27.5	0	0
US	Midway	Aircraft Carrier	3	Midway	CV 41	10-Sep-45	40.4	36	48
US	Oregon City	Heavy Cruiser	3	Oregon City	CA 122	16-Feb-46	11.2	1	1
US	Albany	Guid Msl Cruiser	3	Albany	CG 10	15-Jun-46	33.0	3	4
US	Des Moines	Heavy Cruiser	3	Des Moines	CA 134	16-Nov-48	16.3	1	4
US	Tang	Submarine	6	Tang	SS 563	25-Oct-51	26.1	1	2
US	Mitscher	Destroyer Leader	4	Mitscher	DDG 35	15-May-53	20.0	3	11
US	Dealey	Destroyer Escort	13	Dealey	DE 1006	03-Jun-54	16.3	2	6
US	Thomaston	Dock Landing Ship	8	Thomaston	LSD 28	17-Sep-54	30.7	12	46
US	Nautilus	Nuc Att Submarine	1	Nautilus	SSN 571	30-Sep-54	25.4	11	11
US	Forrestal	Aircraft Carrier	4	Forrestal	CV 59	01-Oct-55	38.0	60	83
US	Forr. Sherman	Destroyer	18	Forr. Sherman	DD 931	09-Nov-55	25.6	28	69
US	Darter	Submarine	1	Darter	SS 576	20-Oct-56	33.1	3	4
US	Seawolf	Nuc Att Submarine	1	Seawolf	SSN 575	30-Mar-57	30.0	3	5
US	Skate	Nuc Att Submarine	4	Skate	SSN 578	23-Dec-57	28.3	10	17

Table 5 (continued): Incident summary for United States Navy ship classes.

Nat.	Ship Class	Type	No.	Lead Ship			Class Avg Yrs	# Incid	Mo. Lost
				Name	ID #	Commis.			
							(active)		
US	Grayback	Guid Msl Submarine	2	Grayback	SSG 574	07-Mar-58	16.0	3	3
US	Galveston	Guid Msl Cruiser	3	Galveston	CLG 3	28-May-58	26.1	4	5
US	Barbel	Att Submarine	3	Barbel	SS 580	17-Jan-59	30.4	7	46
US	Claud Jones	Destroyer Escort	4	Claud Jones	DE 1033	10-Feb-59	14.6	3	7
US	Skipjack	Nuc Att Submarine	6	Skipjack	SSN 585	15-Apr-59	24.9	8	279
US	Triton	Nuc Att Submarine	1	Triton	SSN 586	10-Nov-59	9.5	4	4
US	G. Washington	Ball Msl Submarine	5	G. Washington	SSBN 598	30-Dec-59	22.5	3	12
US	Halibut	Nuc Att Submarine	1	Halibut	SSN 587	04-Jan-60	16.5	0	0
US	Chas. F. Adams	Guid Msl Destroyer	23	Chas. F. Adams	DDG 2	10-Sep-60	28.7	31	58
US	Farragut	Guid Msl Destroyer	10	Farragut	DDG 37	10-Dec-60	30.5	11	14
US	Kitty Hawk	Aircraft Carrier	4	Kitty Hawk	CV 63	29-Apr-61	40.0	50	59
US	Permit	Nuc Att Submarine	14	Thresher	SSN 593	03-Aug-61	24.5	22	326
US	Ethan Allen	Ball Msl Submarine	5	Ethan Allen	SSBN 608	08-Aug-61	25.0	8	21
US	Iwo Jima	Amphibious Assault	7	Iwo Jima	LPH 2	26-Aug-61	31.2	21	41
US	Long Beach	Nuc Guid Msl Cruise	1	Long Beach	CGN 9	09-Sep-61	33.6	0	0
US	Enterprise	Aircraft Carrier	1	Enterprise	CVN 65	25-Nov-61	55.2	10	13
US	Leahy	Guid Msl Cruiser	9	Leahy	CG 16	04-Aug-62	30.5	6	8
US	Raleigh	Amphib Tpt Dock	3	Raleigh	LPD 1	08-Sep-62	33.1	10	14
US	Bainbridge	Nuc Guid Msl Cruise	1	Bainbridge	CGN 25	06-Oct-62	33.9	1	1
US	Lafayette	Ball Msl Submarine	19	Lafayette	SSBN 616	23-Apr-63	27.5	18	93
US	Bronstein	Frigate	2	Bronstein	FF 1037	15-Jun-63	27.3	2	3
US	Belknap	Guid Msl Cruiser	9	Belknap	CG 26	07-Nov-64	27.8	11	63
US	Garcia	Frigate	11	Garcia	FF 1040	21-Dec-64	22.6	9	14
US	Austin	Amphib Tpt Dock	12	Austin	LPD 4	06-Feb-65	40.9	20	42
US	Benj. Franklin	Ball Msl Submarine	12	Benj. Franklin	SSBN 640	22-Oct-65	28.5	11	12
US	Brooke	Guid Msl Frigate	6	Brooke	FFG 1	12-Mar-66	21.3	1	1
US	Sturgeon	Nuc Att Submarine	39	Sturgeon	SSN 637	03-Mar-67	26.0	33	98
US	Truxtun	Nuc Guid Msl Cruise	1	Truxtun	CGN 35	27-May-67	28.3	1	0
US	Charleston	Amphibious Cargo	5	Charleston	LKA 113	14-Dec-68	23.9	3	2
US	Anchorage	Dock Landing Ship	5	Anchorage	LSD 36	15-Mar-69	30.5	5	6
US	Knox	Frigate	46	Knox	FF 1052	12-Apr-69	21.2	35	45
US	Newport	Tank Landing	20	Newport	LST 1179	07-Jun-69	23.8	18	34
US	Blue Ridge	Amphib Command	2	Blue Ridge	LCC 19	14-Nov-70	46.3	3	3
US	California	Nuc Guid Msl Cruise	2	California	CGN 36	16-Feb-74	25.0	3	3
US	Nimitz	Aircraft Carrier	10	Nimitz	CVN 68	03-May-75	26.1	22	27
US	Spruance	Destroyer	31	Spruace	DD 963	20-Sep-75	23.4	24	41

Table 5 (continued): Incident summary for United States Navy ship classes.

Nat.	Ship Class	Type	No.	Lead Ship			Class Avg Yrs	# Incid	Mo. Lost
				Name	ID #	Commis.			
							(active)		
US	Tarawa	Amphibious Assault	5	Tarawa	LHA 1	29-May-76	31.2	8	12
US	Virginia	Nuc Guid Msl Cruiser	4	Virginia	CGN 38	11-Sep-76	17.7	2	3
US	Los Angeles	Nuc Att Submarine	62	Los Angeles	SSN 688	13-Nov-76	25.9	39	326
US	Oliver H. Perry	Guid Msl Frigate	51	Oliver H. Perry	FFG 7	17-Dec-77	24.4	24	46
US	Kidd	Guid Msl Destroyer	4	Kidd	DDG 993	27-Mar-81	17.1	1	0
US	Ohio	Ball Msl Submarine	18	Ohio	SSBN 726	11-Nov-81	28.0	14	19
US	Ticonderoga	Guid Msl Cruiser	27	Ticonderoga	CG 47	22-Jan-83	25.4	25	65
US	Whidbey Island	Dock Landing Ship	8	Whidbey Island	LSD 41	09-Feb-85	28.1	6	6
US	Wasp	Amphibious Assault	8	Wasp	LHD 1	29-Jul-89	19.9	14	16
US	Arleigh Burke	Guid Msl Destroyer	62	Arleigh Burke	DDG 51	04-Jul-91	15.6	36	91
US	Harpers Ferry	Dock Landing Ship	4	Harpers Ferry	LSD 49	07-Jan-95	20.8	2	2
US	Seawolf II	Nuc Att Submarine	3	Seawolf	SSN 21	19-Jul-97	16.7	1	1
US	Virginia II	Nuc Att Submarine	13	Virginia	SSN 774	23-Oct-04	6.4	1	1
US	San Antonio	Amphib Tpt Dock	10	San Antonio	LPD 17	14-Jan-06	6.3	3	3
US	Freedom	Littoral Combat Ship	4	Freedom	LCS 1	08-Nov-08	3.7	2	10
US	Independence	Littoral Combat Ship	4	Independence	LCS 2	16-Jan-10	3.0	0	0
US	America	Amphibious Assault	1	America	LHA 6	11-Oct-14	2.5	0	0
US	Zumwalt	Guid Msl Destroyer	1	Zumwalt	DDG 1000	15-Oct-16	0.4	1	1

3.2 Incidents for Royal Canadian Navy ships

Annex A provides a listing of all 1,254 incidents (as a digital attachment). But to provide the reader with some insight into the nature of the information uncovered during this research, two tables listing subsets of these incidents will be presented here in the main body of this report in this subsection and the next.

The first table comprises a complete list of the 54 incidents identified involving Royal Canadian Navy vessels. They are presented in chronological order below as Table 6, spread over the next three pages.

Table 6: All incidents for Royal Canadian Navy ships.

Ship			Incident			
Name	ID #	Ship Type	Date	Incident Type	Lost Mo.	Description
						* Estimated value
Magnificent	CVL 21	Aircraft Carrier	20-Mar-49	Protest action	1	Aircraft handler 'mutiny' while on manoeuvres in the Caribbean, defused by captain.
Magnificent	CVL 21	Aircraft Carrier	04-Jun-49	Grounding	2*	Ran aground off Nova Scotia, 'some' damage with 2 compartments flooded, refloated with HMCS Nootka assistance, to Saint John for repairs..
Restigouche	DDE 257	Destroyer Escort	21-Nov-57	Collision	3*	Collides with a freighter in the St. Lawrence River.
Chaudiere	DDE 235	Destroyer Escort	01-Jul-58	Fire	8*	Fire breaks out during construction, \$200K in damage, commissioning is delayed.
Skeena	DDH 207	Destroyer Helo Esc	29-Jan-62	Weapon incident	0	While on local operations, accidentally shells a Washington State village.
Bonaventure	CVL 22	Aircraft Carrier	01-Jul-63	Collision	2*	Collides with HMCS Athabaskan 219 during RAS operations while on exercise in the N. Atlantic, 'some' damage, to Scotland for repairs.
Bonaventure	CVL 22	Aircraft Carrier	03-Nov-64	Explosion	2*	Suffers an explosion and fire in a refrigeration unit while undergoing refit in Saint John, NB, 1 death, 4 injured.
Nipigon	DDH 266	Destroyer	18-Oct-65	Fire	3*	Fire breaks out in the fuel handling room, 3 deaths, 8 injured, no official cause determined.
Bras d'Or	FHE 400	Hydrofoil	05-Nov-66	Fire	21*	Flash fire occurs in the engine room, delayed launch to Jul 68, \$5.7M in damage.
Rainbow	SS 75	Submarine	01-Jul-68	Fire	1*	Suffers 2 fires onboard during initial delivery from the US.
Saskatchewan	DDE 262	Destroyer Escort	08-Sep-68	Grounding	1*	Runs aground in the Strait of Georgia, British Columbia.
Kootenay	DDE 258	Destroyer Escort	23-Oct-69	Explosion	6	Gearbox explosion off UK, 9 deaths, 51 injured, repairs merged with IRE conversion, back Jan 72.
Bonaventure	CVL 22	Aircraft Carrier	03-Dec-69	Misc	1*	Improper venting while cleaning aviation fuel tanks causes 2 deaths from fumes, 2 others died in a rescue effort.
Saguenay	DDH 206	Destroyer Helo Esc	16-Jul-70	Grounding	1*	Runs aground off Cape Breton, refloated next day, 'no damage'.
Restigouche	DDE 257	Destroyer Escort	01-Jun-72	Fire	1*	Fire breaks out on a barge moored alongside Restigouche in Halifax, quick response, barge towed off.
Margaree	DDH 230	Destroyer Helo Esc	01-Jun-73	Collision	2*	Collides with a research ship.
Okanagan	S 74	Submarine	28-Jul-73	Collision	3*	Suffers an underwater collision with the tanker Grey Rover during exercises off Scotland, fin and mast damage, no injuries.
St. Laurent	DDH 205	Destroyer Helo Esc	01-Jun-74	Grounding	197	Unspecified 'keel damage' incident, leads to early decommissioning, average class life 35.0 yrs.
Assiniboine	DDH 234	Destroyer Helo Esc	25-Apr-74	Misc	0	In port in Lisbon with HMCS Huron and Yukon when the Carnation Revolution happens, no incidents.

When these five sources came up short for an individual ship or incident, search engines were occasionally able to point to helpful newspaper accounts or personal websites. These sources are too numerous to list beyond references [8] through [11].

Were you able to capture every relevant incident in the operational history of each of these 1,222 ships? The answer has to be ‘no’. The most useful online sources, References [3] through [7] above, all rely on individuals who were present at the time, remembering key events and then ensuring they are documented online for posterity’s sake. For some ships, both older and newer, there are but scant accounts posted, while others in the same ship class might have pages and pages of operational details. But even having pages of detail does not guarantee that the accidents and incidents of interest to this study were mentioned. It is clear to the author that more than a few of the posted ship histories have been written in what might be labelled ‘rose-coloured glasses’ fashion, where well-known incidents are not even mentioned as they might cast a poor light on a past captain or crew members.

To summarize on the completeness of the data, it must be admitted that relevant incidents are missing and there is no way to know how much has been missed (in Rumsfeldian terms, we don’t know what we don’t know). We only know for sure that our incident list is incomplete. The reader must keep that in mind when considering the results of this analysis.

How accurately can the time lost due to each incident be determined? The details obtained from available sources for repair times, back in service times, etc., vary widely from ship to ship and from incident to incident. For many of the incidents, sufficient detail has been uncovered to give an assessment of time lost accurate to the day, although accuracy in terms of weeks or even just months occasionally has to be accepted. Phrases like ‘she was out of repair and continued operations on November 27th’, ‘repairs took a couple of weeks’, or ‘the ship began sea trials early in the new year’ illustrate the variable resolution of these downtime assessments.

For each of the 1,254 incidents captured in this database, the service time lost value is labelled as either supported by researched information, or simply estimated by the author based on the description of the incident and the comparability to other incidents with established service time lost.

The units used for service time lost are *integer months*. Weeks were deemed too high fidelity based on the overall quality of available information. Values are rounded up to the next month, so a value shown of 1 month indicates that the service time lost was *up to* 1 month. A value of 6 months indicates more than 5 months but not more than 6 months, etc.

The reader should be aware that additions and averages of such numbers, which are included in the analysis sections of this report, will have these round-up errors associated. But given the large number of other uncertainties and estimates, including incompleteness of the data, the reader must be cognizant that these arithmetic presentations will carry less statistical substance than one would wish, but are nonetheless capable of providing useful insight into the impact such incidents play in the service life of a naval vessel.

Table 6 (continued): All incidents for Royal Canadian Navy ships.

Ship			Incident			
Name	ID #	Ship Type	Date	Incident Type	Lost Mo.	Description
						* Estimated value
Fredericton	FFH 337	Guid Msl Frigate	18-Nov-10	Collision	1*	Contacts the replenishment ship USNS Kanawha during RAS operations, 'minor' scrapes and dents.
Corner Brook	SSK 878	Submarine	04-Jun-11	Grounding	75	Impacts ground on manoeuvres, 'extensive' bow damage, 2 injuries, repairs began Jul 14 with completion expected in 2017.
Vancouver	FFH 331	Guid Msl Frigate	01-Jul-11	Fire	1*	Suffers a boiler room fire, delaying ship's departure.
Preserver	AOR 510	Replenishment Oiler	04-Nov-11	Grounding	2*	Ship hits Halifax jetty, bow damage, \$0.5M to repair.
Athabaskan	DDH 282	Guid Msl Destroyer	01-Dec-12	Grounding	2*	Breaks tow and grounds off Cape Breton post refit, some hull damage.
Winnipeg	FFH 338	Guid Msl Frigate	23-Apr-13	Collision	9	While alongside at Esquimalt, is rammed by a US factory trawler being towed to Esquimalt graving dock, 6 injured, \$3.1M damage, returned to sea trials by early Jan 14.
Protecteur	AOR 509	Replenishment Oiler	30-Aug-13	Collision	3	Towing incident with HMCS Algonquin en route to Hawaii, 90 days to repair the damaged bow, no injuries.
Algonquin	DDH 283	Guid Msl Destroyer	30-Aug-13	Collision	52	Collides with HMCS Protecteur during towing manoeuvres, hangar damage, led to early decommissioning (planned 2019).
Protecteur	AOR 509	Replenishment Oiler	20-Feb-14	Fire	31	Suffers a major engine room fire and breakdown off Hawaii, 20 injured, engines badly damaged, towed back to Esquimalt, decision was made to decommission early (2017 was planned).
Windsor	SSK 877	Submarine	01-Mar-14	Mech	1*	Suffers a defective diesel generator problem.
Toronto	FFH 333	Guid Msl Frigate	08-Sep-14	Misc	0	Is circled by Russian fighters, no further incidents.
Toronto	FFH 333	Guid Msl Frigate	25-Dec-14	Fire	2*	Suffers a fire in a machinery room, smoke damage.
Athabaskan	DDH 282	Guid Msl Destroyer	01-Mar-15	Weather	1*	Suffers storm damage in sea state 9 conditions.
Ville de Quebec	FFH 332	Guid Msl Frigate	03-Mar-16	Fire	1*	Has a diesel generator fire alongside.

3.3 Major incident list

The second table comprises the major incidents across all five Navies. These are the incidents that entailed five months or more of service time lost (actual or estimated) for the vessel involved, and are presented below as Table 7, spread over the next nine pages. These incidents are listed in decreasing order of service time lost. Note that for the sake of completeness, this list also includes non-peacetime incidents (type 'Attacked', shaded grey). A total of nine vessels were irretrievably sunk, of which four were Royal Navy ships sunk during the Falklands War.

Table 7: Major incident list (5 or more months of service time lost).

Ship		Incident			
Name	Ship Type	Date	Incident Type	Lost Mo.	Description
* Estimated value					
USS Thresher	Nuclear Attack Sub	10-Apr-63	Mechanical	295	Implodes and sinks in 8,400 feet of water 200 mi east of Boston during post-overhaul trials, all 129 died, assessed a piping system failure, never recovered, average class life 26.3 yrs.
HMS Coventry	Guided Msl Destroyer	25-May-82	Attacked	278	Hit and sunk by 3 bombs from an Argentinian A-4, average class life 26.8 yrs.
USS Scorpion	Nuclear Attack Sub	27-May-68	Unknown	250	Sinks off Azores in 10,000 ft of ocean, all 99 died, cause undetermined, 2 nuclear ASTOR torpedoes believed onboard, class life for 4 others is 28.7 yrs.
HMS Sheffield	Guided Msl Destroyer	04-May-82	Attacked	235	Attacked and sunk by Argentinian Super Etendard's Exocet ASM while guarding the fleet perimeter, sank one week later, fire killed 20 crew, average class life 26.8 yrs.
HMS Affray	Submarine	16-Apr-51	Unknown	234	Lost at sea in the English Channel during exercises, 75 deaths, no specific cause determined, sits in 83m of water, average class life 24.6 yrs
HMAS Voyager	Destroyer	10-Feb-64	Collision	204	Collided with aircraft carrier HMAS Melbourne, was sliced in half and sank, 82 crew died, average class life 24 yrs
HMCS St. Laurent	Destroyer Helo Escort	Jun-74	Grounding	197	Unspecified 'keel damage' caused early decommissioning, average class life 35.0 yrs.
HMS Ardent	Frigate	21-May-82	Attacked	151	Hit by 9 bombs from Argentine A-4s and sunk, 21 May 82, 22 crew killed, average class life 17.5 yrs.
USS Miami	Nuclear Attack Sub	24-May-12	Sabotage	135	Arsonist sets a fire onboard while in Portsmouth, NH, for its engineering overhaul, 12 hours to extinguish, 7 injuries, estimated \$700M to repair, decision taken to deactivate on 6 Aug 13 citing forfeit of 10 years of future service.
HMS Antelope	Frigate	23-May-82	Attacked	127	Bombed by Argentine A-4s and sunk, bombs failed to detonate but defusing triggered detonation, 2 crew killed, average class life 17.5 yrs.
HMCS Chicoutimi	Submarine	05-Oct-04	Fire	97	Major flood and electrical fire en route to Canada, out of service for repairs from Oct 04 to Nov 13
HMCS Corner Brook	Submarine	04-Jun-11	Grounding	75	Impacted ground on manoeuvres, 'extensive' bow damage, 2 injuries, repairs began Jul 14 with completion expected in 2017
USS Nathanael Greene	Ballistic Missile Sub	13-Mar-86	Grounding	70	Runs aground in the Irish Sea, damage to ballast tanks and rudder, no injuries, no nuclear issues, damage leads to early decommissioning, partly to satisfy SALT II, avg class life 27.8 yrs.
HMS Ennerdale	Oiler	01-Jun-70	Grounding	67	Auxiliary fleet tanker hit uncharted rocks off Sechelles and sank, 5.7 years short of Dale class average life

Table 7 (continued): Major incident list (5 or more months of service time lost).

Ship			Incident			
Name	Ship Type	Date	Incident Type	Lost Mo.	Description	
					* Estimated value	
USS	Belknap	Guided Msl Cruiser	22-Nov-75	Collision	54	Collided in rough seas with aircraft carrier US John F. Kennedy during air exercises off Sicily, ammunition from the 3" gun storage lockers 'cooked off', 'broken arrow' message sent (high probability of nuclear weapon problem), aluminum superstructure melted nearly to her deck, 2.5 hours to extinguish, 7 deaths (6 from Belknap), no nuclear issues, in repair until 10 May 80.
HMCS	Algonquin	Guided Msl Destroyer	30-Aug-13	Collision	52	Collision with HMCS Protecteur in towing manoeuvres, hangar damage, led to early decommissioning (planned 2019)
USS	San Francisco	Nuclear Attack Sub	08-Jan-05	Grounding	45	Hits an seamount at high speed and 525 ft depth near Guam, 1 death, 23 injured, bow is crushed, temporary repairs in Guam by Aug, refitted with USS Honolulu's bow in Puget Sound, completed \$134M job on 20 Oct 2008
USS	Baton Rouge	Nuclear Attack Sub	11-Feb-92	Collision	43	Collides with Soviet Sierra-class submarine in Barents Sea, details not made public, returned under own power, decision made to decommission early, other 11 'peace dividend' retired boats had avg life of 18.2 yrs.
USS	Warrington	Destroyer	17-Jul-72	Attacked	39	Struck 2 ditched US mines off Vietnam on the port side, 'severe' damage to the fireroom, engine room, and main control room, ruptured oil and water tanks caused flooding, designated unfit for further service and decommissioned, average class life 30.0 years.
HMS	Albion	Aircraft Carrier	18-Oct-49	Collision	36	Collided with another ship under tow before completion, 20 sqm hole!, delayed completion 3 years
USS	Guitarro	Nuclear Attack Sub	15-May-69	Flooding	32	Sinks in 35 feet of water at the shipyard pier in Vallejo, CA, post-launch, shipyard worker negligence, \$35M damage, 32 month delay in commissioning.
HMCS	Protecteur	Oiler	20-Feb-14	Fire	31	Suffers a 'major' engine room fire and breakdown off Hawaii, 20 injured, engines badly damaged, towed back to Esquimalt, decision was made to decommission early (2017 was planned)
USS	Bonefish	Attack Sub	24-Apr-88	Explosion	26	Explosion and major fire when water leaks into the battery compartment while operating submerged in the Caribbean, 3 deaths, decision taken to decommission, average class life 31.0 yrs.
USS	Fort Snelling	Dock Landing	Oct-83	Attacked	25	Intentionally rammed by a merchant vessel while conducting refuelling operations with USS Sylvania off Lebanon, damage led to decommissioning shortly thereafter, average class life 30.9 yrs.

Table 7 (continued): Major incident list (5 or more months of service time lost).

Ship			Incident			
Name	Ship Type	Date	Incident Type	Lost Mo.	Description	
					* Estimated value	
HMAS	Westralia	Oiler	05-May-98	Fire	24	Engine room fire, four crew died, returned to service `during 2000``
HMNZS	Pukaki	Frigate	01-Jan-64	Weather	24	Supporting US Antarctic operations 'Deep Freeze' exposed Pukaki to sea conditions that shortened its life by an estimated 2 years.
HMNZS	Rotoiti	Frigate	01-Jan-64	Weather	24	Supporting US Antarctic operations 'Deep Freeze' exposed Rotoiti to sea conditions that shortened its life by an estimated 2 years.
HMS	Bulwark	Aircraft Carrier	15-Mar-79	Fire	24	Fire in one boiler while alongside in the USA, never restored to operational condition.
HMS	Eastbourne	Frigate	01-Jul-76	Collision	24*	Collision w. Iceland gunboat Baldur (3rd Cod War), damaged to extent that she was rendered a harbour training ship thereafter.
HMS	Glamorgan	Guided Msl Destroyer	Jun-82	Attacked	24*	Struck by land-launched Exocet, hangar and helo destroyed, 14 deaths, fires extinguished & underway in 4.5 hrs.
HMS	Superb	Nuclear-Power Sub	26-May-08	Grounding	24*	Hit underwater pinnacle in Red Sea, sonar damage forced return to UK, and induced early retirement.
HMS	Sceptre	Nuclear-Power Sub	23-May-81	Collision	24*	Collided with Soviet Delta class sub, never publicly reported, fin and bridge damage, outer casing torn away, Soviet prop damaged the pressure hull.
HMS	Amazon	Frigate	01-Jul-77	Fire	24*	Suffers a fire, which is overly severe due to the aluminum structure of the Type 21 class (only class to be built of aluminum).
HMS	Nottingham	Guided Msl Destroyer	07-Jul-02	Grounding	24	Ran aground on Wolfe Rock off Australia, 50 m hole almost sank ship, repairs took 24 months.
HMS	Fort Victoria	Oiler	06-Sep-90	Terrorism	24	IRA planted two bombs onboard, one holed engine room causing list of 45 deg, second bomb disabled after 2 weeks, two year delay in commissioning
USS	Hartford	Nuclear Attack Sub	20-Mar-09	Collision	24	Collides with amphibious transport dock USS New Orleans in Strait of Hormuz, 15 injured, \$120M to repair, completed Feb 11.
HMAS	Waller	Submarine	27-Feb-14	Fire	22	Fire while running on surface, no injuries repairs completed end 2015.
USS	Scamp	Nuclear Attack Sub	24-Feb-87	Weather	22	During a N. Atlantic storm, experienced flooding and sail damage while attempting to rescue the crew of a sinking Philippine freighter, led to early retirement, avg class life for 4 others is 28.7 yrs.
HMCS	Bras d'Or	Hydrofoil	05-Nov-66	Fire	21*	Flash fire occurs in the engine room, delayed launch to Jul 68, \$5.7M in damage.
USS	Porter	Guided Msl Destroyer	12-Aug-12	Collision	20	Collided with a Japanese merchant ship near the Strait of Hormuz, 'extensive' damage to forward starboard hull (photos), 10 by 10-foot hole, \$700K in temporary repairs in Dubai, full repairs in Norfolk completed Apr 14.

Table 7 (continued): Major incident list (5 or more months of service time lost).

Ship			Incident			
Name	Ship Type	Date	Incident Type	Lost Mo.	Description	
					* Estimated value	
HMS	Penelope	Frigate	01-Jul-88	Collision	18* Collided with HMCS Preserver during RAS operations, cutting port side, 'millions' in damage.	
HMS	Argonaut	Frigate	May-82	Attacked	18* Hit by two bombs from Argentine A-4, 21 May 82, neither exploded, later defused, 2 crew killed.	
USS	Iowa	Battleship	19-Apr-89	Explosion	18 Number 2 16-inch gun turret explodes during gunnery exercise, 47 deaths, decommissioned.	
USS	Conyngham	Guided Msl Destroyer	08-May-90	Fire	18 Major fuel oil fire in forward fire room spreads into superstructure, took all hands and 23 hours to extinguish, 1 death, 16 injuries, decommissioned shortly thereafter (avg class life 28.7 yrs).	
USS	Cole	Guided Msl Destroyer	12-Oct-00	Terrorism	18 Attacked in the port of Aden, Yemen, by an explosive-laden small boat on a suicide mission, detonating on the port side and opening a 60 by 40 foot gash, 17 deaths, 39 injured, heavy-lifted to the US for repairs in Mississippi, completed sea trials 19 Apr 02.	
USS	Frank Knox	Destroyer	18-Jul-65	Grounding	14 Runs aground on Pratas Reef in the South China Sea, 'badly damaged', bashed by 2 typhoons, hull holed and flooded, finally pulled free on 22 August, repaired in Japan over the next year.	
USS	Ernest G. Small	Destroyer	07-Oct-51	Attacked	14 Struck a mine off N. Korea, 'extensive' damage to bow, broke off 4 days later in heavy seas, 9 deaths, 18 injured, patched in Japan, returned to California, returned to service 2 Dec 52.	
USS	Decatur	Destroyer	06-May-64	Collision	14 Collides with the aircraft carrier USS Lake Champlain off Virginia, 'heavy' damage to superstructure, no injuries, unrepaired until entering upgrade work 15 Jun 65.	
USS	Ray	Nuclear Attack Sub	20-Sep-77	Grounding	14 Strikes a coral mountain while submerged off Tunisia, nose 'blown' open, sonar equipment destroyed, cracks in the hull, proceeded to Sardinia then US for repairs requiring 12 months at Charleston.	
HMS	Southampton	Guided Msl Destroyer	02-Sep-88	Collision	13 Collision with a container ship being escorted into the Persian Gulf, out of service for 13 month repair costing GBP 45M.	
USS	Thomas A. Edison	Ballistic Missile Sub	29-Nov-82	Collision	13 While running at periscope depth and preparing to surface, collides with destroyer USS Leftwich in South China Sea, top half of sail is bashed (photo), damaged sail planes and sonar dome, no flooding, the boat never dove again, selected as one of the early decommissioning candidates as a result.	
HMS	Artemis	Submarine	01-Jul-71	Misc	12* Sank alongside while refuelling with open hatches and error in trim, raised 5 days later then sold for scrap, no indication of planned retirement but age was at average class life.	

Table 7 (continued): Major incident list (5 or more months of service time lost).

Ship			Incident			
Name	Ship Type	Date	Incident Type	Lost Mo.	Description	
					* Estimated value	
HMS	Battleaxe	Destroyer	01-Aug-62	Collision	12*	Collision with HMS Ursa off Clyde estuary during exercises, hit athwartships so 'consequential' damage considered not economical to repair, at average class life anyway.
HMS	Plymouth	Frigate	08-Jun-82	Attacked	12*	Hit by 4 bombs and cannon fire from Argentine aircraft, fires controlled, funnel damaged, ASW mortar destroyed, 5 injuries.
HMS	Falmouth	Frigate	05-Dec-61	Collision	12*	Collided with oiler RFA Tideflow, 'badly' damaged.
USS	Floyd B. Parks	Destroyer	11-Mar-56	Collision	12*	Collides with heavy cruiser USS Columbus off Philippines, lost 40 feet of her bow, 2 deaths, bow replaced in Long Beach shipyard, CA.
USS	Manley	Destroyer	01-Feb-79	Fire	12*	Forward boiler room fire while preparing to depart Mayport, FL, 1 death, 11 injured, \$75M to repair.
USS	Samuel B. Roberts	Guided Msl Frigate	14-Apr-88	Attacked	12	Strikes a mine in Persian Gulf, causing 'major' structural damage, flooding and fires, 69 injured, returned to US by heavy lift ship, undocked from repairs 1 Apr 89.
USS	Bennington	Aircraft Carrier	26-May-54	Explosion	10	Catapult fluid exploded, setting off a series of explosions and fires operating off Rhode Island, 103 deaths, 201 injured, completed repairs and rebuild by 19 Mar 55, USN changed to steam catapults after this incident.
USS	Montpelier	Nuclear Attack Sub	13-Oct-12	Collision	10	Collides with cruiser USS San Jacinto while rising to periscope depth during exercises off Florida, no injuries, rudder detached, \$70M to repair, completed Jul 13.
USS	Hue City	Guided Msl Cruiser	14-Apr-14	Fire	10	Fire in No. 1 gas turbine generator room off Bermuda, spread quickly through exhaust uptakes to other decks, extinguished in under 2 hrs, abandoned deployment to return to Mayport for repairs, assessed cause was improper storage of combustible materials, \$23.2M in repairs, over 9 months to repair.
USS	Gonzalez	Guided Msl Destroyer	12-Nov-96	Grounding	10	Ran aground on a coral reef off St. Maarten in the Caribbean, 'extensive' damage, towed back to Maine for \$10M in repairs to shafts, propellers, and the sonar dome, back in service Sep 97.
USS	Saint Paul	Heavy Cruiser	21-Apr-52	Explosion	9	Suffers a powder blast in a 8" gun turret off Korea, 30 deaths, in US for repairs from 24 Jun 52 to 28 Feb 53.
USS	Inchon	Amphibious Assault	19-Oct-01	Fire	9	Fire is discovered while at Ingleside, TX, extinguished within 1 hour, 1 death, 7 injured, decision taken to decommission rather than repair, at average class life of 32 years.

Table 7 (continued): Major incident list (5 or more months of service time lost).

Ship			Incident			
Name	Ship Type	Date	Incident Type	Lost Mo.	Description	
					* Estimated value	
USS	Sturgeon	Nuclear Attack Sub	21-May-73	Grounding	9	Ran aground at 10 kts in a deep water dive off US Virgin Islands, 'minor' damage to bow, returned to Groton, CT, to repair, at sea 17 Jul to 1 Oct, into Portsmouth to finalize bow repairs, returned to operations 22 Apr 74.
USS	Hartford	Nuclear Attack Sub	25-Oct-03	Grounding	9	Ran aground off Sardinia, damaging rudders, sonar, and bottom, no injuries, \$9M in damage, entered repairs in Norfolk 17 Dec, repairs took 7 months.
USS	Port Royal	Guided Msl Cruiser	05-Feb-09	Grounding	9	Ran aground off Honolulu airport on sea trials, stuck for 4 days with 'major' effort to free, damage to sonar dome, sheared off propeller blades, 7 months in drydock, completed Oct 09.
HMCS	Winnipeg	Guided Msl Frigate	23-Apr-13	Collision	9	While alongside on C Jetty, rammed by US factory trawler being towed to Esquimalt graving dock, 6 injured, \$3.1M damage, sea trials begin early Jan.
HMCS	Saguenay	Destroyer Helo Escort	16-Aug-86	Collision	8	Collided with German sub U-17 during a NATO exercise, sent home for repairs, back in service 1987.
HMCS	Chaudiere	Destroyer Escort	01-Jul-58	Fire	8*	Fire during construction, \$200K damage and delayed commissioning.
HMS	Broadsword	Frigate	25-May-82	Attacked	8*	Hit by Argentinian A-4 bomb, which didn't detonate but damaged helo and helo deck.
HMS	Trafalgar	Nuclear-Power Sub	Nov-02	Grounding	8*	Grounded near the Isle of Skye at 15 kts, GBP 5M hull damage, 3 injuries.
HMS	Talent	Nuclear-Power Sub	01-Jul-14	Grounding	8*	Struck icebergs while tracking Russian vessels, not reported until 2015, GBP 0.5M to repair 2 m dent in conning tower and acoustic tile damage.
USS	Willis A. Lee	Destroyer Leader	18-Mar-56	Grounding	8	Driven onto the rocks in a storm off Jamestown, RI, spent 'considerable' time in Boston shipyard, returning to service in Nov.
USS	Barbel	Attack Submarine	01-May-89	Flooding	8	A wave washes 3 crew from the deck while conducting surface operations, 2 deaths, extensive damage due to flooding was experienced, decision taken to decommission.
USS	Constellation	Aircraft Carrier	19-Dec-60	Fire	8	During construction in Brooklyn, NY, (90% completed) a forklift ruptures a fuel tank into the hangar bay where welders are at work, igniting a fire, 12 hours to extinguish, 50 deaths, hundreds injured, 'heavily' damaged, commissioning for early 61 delayed to 27 Oct 61.
USS	Art. W. Radford	Destroyer	04-Feb-99	Collision	8	Collides with Saudi RO-RO ship entering Chesapeake Bay, 'heavily' damaged, 25' gash from deck to waterline, toppling 5" gun and damaging Tomahawk tubes, 13 injuries, \$33M damage,

Table 7 (continued): Major incident list (5 or more months of service time lost).

					* Estimated value
USS Princeton	Guided Msl Cruiser	18-Feb-91	Attacked	8*	Hits an Iraqi mine in the Persian Gulf, 'substantial' damage included cracked superstructure, deck buckling, rudder, propeller and shaft damage, flooding in a switchboard room, 'a few' injuries.
USS Chancellorville	Guided Msl Cruiser	16-Nov-13	Weapon incident	8	Hit by a malfunctioning BQM-74 drone during weapon system tests off Point Mugu, CA, 2 injured, returned for damage assessment which was more serious than expected, 6 months and \$30M of 'emergent' repairs began in January.
USS Boxer	Aircraft Carrier	05-Aug-52	Explosion	7	Explosion and fire off Korea, 9 deaths, emergency repairs in Japan completed 23 Aug, full repairs in San Francisco Sep 52 to Mar 53.
USS Theodore Roosevelt	Ballistic Missile Sub	13-Mar-68	Grounding	7*	Runs aground while submerged off Scotland, bow damage, no injuries, repairs in New London, CT, completed by mid-Oct 68.
USS Denver	Amphibious Transport Dock	13-Jul-00	Collision	7	Collides with the oiler USS Yukon during RAS operations west of Hawaii, gaping 40-foot hole in the bow to the waterline (photos), no injuries, no fuel leaks, temporary repairs at Pearl Harbour, full repair at San Diego, completed 23 Jan 01.
USS San Jacinto	Guided Msl Cruiser	13-Oct-12	Collision	7	Submarine USS Montpelier rises to periscope depth in front of the cruiser during exercises off Florida, sonar dome, hull, and peripheral equipment damaged, entered Mayport drydock 1 Nov, \$11M in repairs, operational before 31 May.
USS Freedom	Littoral Combat	Feb-11	Weather	7	Sprung hull crack in heavy weather trials (faulty welds), minor flooding, repaired by 19 Sep.
HMCS Kootenay	Destroyer Escort	23-Oct-69	Explosion	6	Gearbox explosion off UK, 9 deaths, 51 injured, repairs merged with IRE conversion, out to Jan 72
HMS Diamond	Destroyer	29-Sep-53	Collision	6*	Collided with a cruiser during exercise off Iceland, 'severe' bow damage.
HMS Lincoln	Frigate	Oct-73	Collision	6*	Mutual ramming with Iceland gunship Odinn (2nd Cod War) up to 3 times, and was 'substantially' damaged, returned for repairs.
HMS Ashanti	Frigate	01-Jul-77	Fire	6*	Fire in boiler room, 3 crew members die of carbon monoxide poisoning.
HMS Minerva	Frigate	01-Jul-79	Explosion	6*	Boiler explosion immobilized ship, towed to repair.
HMS Argonaut	Frigate	21-May-82	Attacked	6*	Hit by cannon fire and rockets from Argentine MB-339, some damage including radar.
HMS Ambush	Nuclear-Pow Submarine	20-Jul-16	Collision	6*	Collided with merchant ship off Gibraltar while surfacing during exercise, 'significant' conning tower damage.
USS Ozbourn	Destroyer	23-Nov-48	Collision	6*	Collides with sister ship USS Theodore E. Chandler during high-speed, darkened-ship, night maneuvers off Tsingtao, China, damage control saved ship, 2 deaths, most of the bow was sheared off.

Table 7 (continued): Major incident list (5 or more months of service time lost).

Ship		Incident			
Name	Ship Type	Date	Incident Type	Lost Mo.	Description
* Estimated value					
USS Charles H. Roan	Destroyer	08-Nov-50	Collision	6*	Collides with sister ship USS Brownson in Atlantic during nighttime fleet maneuvers at 20 kts and running dark, large hole in aft engine room and machine shop, 5 deaths, several injured.
USS Duncan	Destroyer	01-Mar-48	Explosion	6*	Magazine explosion suffered while operating in the Pacific, 'considerable' damage at stern, flooding after compartment from waterline hole, 2 deaths, 14 injured, returning before Jan 49.
USS Newman K. Perry	Destroyer	26-Aug-65	Collision	6*	Collides with carrier USS Shangri-La off Sardinia, 1 death, 1 injured, bow crushed and twisted, repaired at Naples.
USS Forrestal	Aircraft Carrier	29-Jul-67	Weapon incident	6*	A Zuni rocket inadvertently fired from an aircraft being prepared for launch, strikes the fueled drop tank of another aircraft and explodes, 134 deaths, 63 aircraft damaged or destroyed.
USS Barbel	Attack Sub	30-Nov-60	Flooding	6*	Suffers flooding when diving to test depth (700') during an exercise off the eastern US, a 5" seawater cooling line ruptured spilling 350 tons of water into the engine room, emergency blow, all piping over 2" replaced at Portsmouth, NH.
USS Sampson	Guided Msl Destroyer	14-Jan-65	Fire	6	Electrical fire caused extensive damage to her fire control capability, returned to Norfolk, repairs completed 24 Jun.
USS Iwo Jima	Amphibious Assault	03-Mar-75	Collision	6*	Loses steering control and crashes into the amphibious transport dock USS Nashville during a highline transfer south of the Azores, 'severely' damaged.
USS Nashville	Amphibious Transport Dock	03-Mar-75	Collision	6*	The amphibious assault ship USS Iwo Jima loses steering control and rams Nashville during highline transfer in the Atlantic south of the Azores, both 'severely' damaged.
USS Tautog	Nuclear Attack Sub	20-Jun-70	Collision	6*	Soviet Echo II sub descends into Tautog's sail off Kamchatka, imbedding part of the propeller and leaving the sail permanently bent 2 deg.
USS Newport News	Nuclear Attack Sub	08-Jan-07	Collision	6*	Collides with Japanese oil tanker in the Strait of Hormuz while transiting submerged, no injuries, bow damage, ship went to Bahrain for repairs and left the gulf 10 Apr for a complete overhaul.
USS Kidd	Guided Msl Destroyer	29-Aug-05	Weather	6	Damaged by Hurricane Katrina while under construction in Mississippi, holed and partially flooded, forced a return to drydock, delayed commissioning 6 months.
USS Truxtun	Guided Msl Destroyer	20-May-06	Fire	6*	During construction in Mississippi, suffered a major electrical fire, damage in the millions, commissioning delayed.

Table 7 (continued): Major incident list (5 or more months of service time lost).

Ship		Incident			
Name	Ship Type	Date	Incident Type	Lost Mo.	Description
* Estimated value					
HMAS Melbourne	Aircraft Carrier	03-Jun-69	Collision	5	Collide with and sinks destroyer USS Frank E. Evans during exercises in the South China Sea, 74 deaths on Evans which was sliced in half, bow repairs on Melbourne completed 7 Oct 69.
USS Oriskany	Aircraft Carrier	27-Oct-66	Fire	5	'Major' fire occurs in the forward hanger bay during operations off Vietnam, a flare was accidentally thrown into a storage locker with 650 other flares, the fire raced through 5 decks and took 3 hours to control, 44 deaths, 6 aircraft damaged, repairs completed 23 Mar 67.
USS Basilone	Destroyer	15-Jun-63	Weather	5*	Sustains a hull crack during a severe storm off Ireland, leaking 30 gallons/minute, sent back to the US for repairs, after several unsuccessful fixes went to Philadelphia shipyard for a complete overhaul, ready 26 Apr 64.
USS Basilone	Destroyer	05-Feb-73	Explosion	5	Suffers a boiler room explosion during training SE of New York City, 7 deaths, returned to operational status on 30 Jul.
USS Norris	Destroyer	01-Nov-54	Collision	5*	Rams the superstructure of sub USS Bergall during exercises off Norfolk, five compartments flooded.
USS Bordelon	Destroyer	14-Sep-76	Collision	5	Steering control difficulties during refuelling causes it to crash into the carrier USS John F. Kennedy off Scotland, port bow and superstructure damaged, main mast snapped and fell on the signal shack, injuring 6, USN decommissions rather than repair (avg class age 30.0 yrs).
USS Brinkley Bass	Destroyer	04-Feb-66	Collision	5	Collides with destroyer USS Waddell while forming for operations in the Gulf of Tonkin, 'heavily' damaged the bow, out of drydock on 21 Jun.
USS Manley	Destroyer	12-Dec-57	Weather	5	Broadsided by 'tremendous' wave in E. Atlantic, 80 kt winds, 2 deaths, several injured, 'heavy' damage to galley, radio, and radar rooms from subsequent flooding, not fully repaired until 29 Apr 58.
USS Tattall	Guided Msl Destroyer	24-Jan-84	Fire	5	Fire knocks out anti-aircraft and Harpoon capabilities off Syria, returned for repairs, out till 4 June.
USS Halsey	Guided Msl Destroyer	15-Dec-06	Fire	5	Damage from the Nov fire leads to another fire and explosion during a Pacific exercise, \$8.5M to repair, out of San Diego drydock 4 May 07.

4 Analysis of peacetime incidents

There is a range of questions that naturally arises, and each subsection that follows will investigate and provide answers to each, to the limit of what the incident database will support. Of the 1,254 incidents identified over the five Navies, 1,158 were peacetime incidents.

4.1 Analysis by incident type

Table 8 presents the number of incidents and the average service time lost for each of the 17 incident types employed. The average service time lost over all 1,158 peacetime incidents was 3.80 months.

Table 8: Summary by incident type.

Type	No. of Incidents	Percent	Avg Time Lost
Collision	362	31.3%	3.5
Fire	194	16.8%	3.0
Grounding	155	13.4%	5.2
Weather	90	7.8%	2.4
Aircraft crash	70	6.0%	1.1
Explosion	68	5.9%	3.0
Mechanical	45	3.9%	7.8 ¹
Miscellaneous	42	3.6%	1.0
Weapon incident	40	3.5%	1.2
Flooding	29	2.5%	2.9
Fouling	20	1.7%	0.9
Nuclear incident	19	1.6%	1.0
Sabotage	11	0.9%	13.5 ²
Protest action	7	0.6%	0.7
Terrorism	4	0.3%	10.5
Unknown	2	0.2%	242.0
Overall	1,158	100.0%	3.80
Attacked	96		11.0
¹ reduces to 1.30 if USS THRESHER incident excluded.			
² reduces to 1.30 if USS MIAMI incident excluded.			

Which types of incidents occur most frequently? By a wide margin, the most frequent type is *Collision* with 31.3% of all peacetime incidents, although keep in mind there is some double counting to consider when both ships involved in the incident are included in this database. *Fire* and *Grounding* were the second and third most frequent with 16.8% and 13.4% of all peacetime incidents respectively.

Which types of incidents tend to incur the most service time lost? Excluding the two *Unknown* incidents (in which submarines were lost), three incident types exceed by more than 100% the average time lost value of 3.80 months.

One of those is *Terrorism*. There are only four *Terrorism* incidents, but the Irish Republican Army attack on the HMS FORT VICTORIA while under construction in 1990, and the al Qaeda attack on the USS COLE in Yemen in 2000 were the main contributors to an average of 10.5 months lost per incident.

The two other types are *Sabotage* at 13.5 and *Mechanical* at 7.8 average months lost. But these two both reduce to a very low value of 1.3 average months lost if just two individual incidents are excluded. The USS MIAMI *Sabotage* incident entailed 135 months of lost service time, and the USS THRESHER *Mechanical* incident, which sank the sub, entailed 295 months of lost service.

Of the most frequently occurring incident types, *Grounding* tends to do the most damage (longest recovery time), with an average of 5.2 months lost. This might be expected, as any subsequent repair will almost certainly require dry-docking. Compare this to *Collision* which generates an average 3.5 months lost, close to the overall average of 3.80 months.

Which types of incidents tend to incur the least service time lost? Some of the incident types that incurred the least damage are those one might expect. *Protest action* tends to produce the threat of damage more than actual damage, and *Fouling*, in which submarines accidentally snag tow cables or fishing nets, tends to do more damage to the surface ships affected than the submarine. *Miscellaneous*, almost by definition one might suppose, also tends to result in minimal time lost.

However, three types of incidents that were observed to result in minimal damage are perhaps not so intuitive: *Weapon incident*, *Aircraft crash*, and *Nuclear incident*.

Certainly a *Weapon incident* can be disastrous if the weapon detonates, but of the 40 incidents so classified only a single incident can be considered disastrous: a rocket misfire while loading an aircraft on the aircraft carrier USS Nimitz in 1967 which ignited fuel tanks on other aircraft and resulted in 134 deaths.

An *Aircraft crash* onboard a ship has the potential to cause serious damage to the ship as well, and certainly numerous aircraft were lost in the 70 incidents noted. Mostly, it was the rugged flight deck that bore the brunt of the impact with little resulting damage and downtime. Also keep in mind that aircraft carriers can do a lot of their own repairs, and get to the front of the service queue when there is more substantial damage to repair. In only three incidents did the crashing aircraft inflict any substantial damage to the superstructure of the ship, and these were all helicopter mishaps.

It is a positive statement on safety standards for nuclear weapons and power plants that all of the 19 *Nuclear incidents* identified were relatively insignificant. Table 9 below lists the details of each of these incidents in chronological order. All are associated with US Navy vessels. Notably, only two such incidents are known to have occurred in the last 30 years.

Table 9: Nuclear incidents list.

Ship		Nuclear Incident		
Name	Ship Type	Date	Lost Mo.	Description
* Estimated value				
USS Seawolf	Nuclear Att Submarine	19-Aug-56	3*	The experimental sodium-cooled reactor suffers a failure in Groton, CT, construction yard, causing cracks and leaks, completed sea trials in Feb 57 on reduced power, but reactor is replaced with a water-cooled one, delaying commissioning, old reactor dumped in Atlantic at 9,000 ft.
USS Nautilus	Nuclear Att Submarine	01-Nov-60	1*	6 men are soaked with reactor coolant when a valve is accidentally bumped while in Portsmouth, NH.
USS Ticonderoga	Aircraft Carrier	05-Dec-65	1*	An A-4E aircraft with a B43 nuclear weapon onboard rolls off the elevator and goes overboard, sinks in 2,700 fathoms, pilot died, 200 miles off Okinawa.
USS Luce	Guided Msl Destroyer	19-Jan-66	1*	Nuclear warhead on terrier A/A missile separates from missile and drops 8 feet, docked at Mayport Naval Station, Florida, no casualties, warhead dented, no damage.
USS Dace	Nuclear Att Submarine	29-Dec-71	1*	500 gal of reactor coolant water is discharged into Thames River at New London, CT, during a routine water transfer, 'very small' amount of radioactive material released.
USS Guardfish	Nuclear Att Submarine	Apr-73	3*	Primary coolant leak occurs while running submerged off Washington State, sub surfaces and is ventilated and decontaminated and repairs the fault unassisted, 4 crew sent for monitoring.
USS California	Nuclear GM Cruiser	01-Jul-75	1*	Reportedly spilled 15-20 gallons of primary coolant while at Norfolk base.
USS Albany	Guided Msl Cruiser	16-Apr-76	1*	A top-side hoist fails when handling TALOS nuclear warheads, no injuries, considered an official nuclear weapons 'dull sword' (minor handling) incident.
USS California	Nuclear GM Cruiser	01-Jul-77	1*	Reportedly spilled 40-50 gallons of primary coolant while at Norfolk base.
USS Puffer	Nuclear Att Submarine	23-May-78	1*	Mistakenly opened valve releases an amount (5 gal to 100 gal) of radioactive water onto the drydock floor at Bremerton, WA, jackhammered up and disposed of.
USS Aspro	Nuclear Att Submarine	26-May-78	0	Small amount of radioactive water (2 cups) leaks from a pipe fitting due to improperly shut valve, no exposure issues.
USS Nimitz	Aircraft Carrier	11-May-79	1*	Primary coolant water leaks from one of the two reactors, no radioactivity release or danger.
USS Hawkbill	Nuclear Att Submarine	20-Jun-79	1*	Faulty valve causes a primary reactor coolant system leak (initially 2 gal/hr) while on maneuvers off Hawaii, stopped by 24 Jun, no external leakage, no injuries.
USS Truxtun	Nuclear GM Cruiser	02-Sep-79	0	Spills about 13 gallons of radioactive 'high purity' water into San Diego Bay, no radiation concern.
USS Gurnard	Nuclear Att Submarine	20-Jul-80	0	Spills 30 gal of radioactive water into San Diego Bay after a valve is accidentally opened.
USS Hawkbill	Nuclear Att Submarine	03-Dec-80	1*	During a test about 150 gal of radioactive water leaks from a faulty valve while undergoing overhaul at Puget Sound shipyard, no injuries.

Table 9 (continued): Nuclear incidents list.

Ship			Nuclear Incident		
Name	Ship Type	Date	Lost Mo.	Description	
				* Estimated value	
USS Sam Rayburn	Ballistic Missile Sub	02-Apr-84	0	Controversy when the Glasgow Herald reports the Rayburn had mildly radioactive paint, US Navy says level so low it cannot be detected.	
USS Abraham Lincoln	Aircraft Carrier	27-Jul-89	1*	About 300 gallons of coolant spills into the James River while docked at Newport News, radioactivity released assessed as 'miniscule'.	
USS Georgia	Ballistic Missile Sub	07-Nov-03	1*	While unloading Trident missiles at Bangor, WA, a ladder is left in tube 16 cutting a 9-inch hole in the missile's nose cone, no radioactive material released.	

4.2 Distribution of lost service times

A simple tabulation of the service time lost values for the 1,158 peacetime incidents is a good place to begin, and these are presented below in Table 10. Note that 53 of the incidents captured had the potential to impact the service life of the vessel, but by good fortune did not. Examples of these no-time-lost incidents can be seen in Tables 6 and 9.

Table 10: Tabulation of service time lost values for peacetime incidents.

Service Time Lost	No. of Incidents	Percent
no lost time	53	4.6
1 mo.	624	53.9
2 mo.	262	22.6
3 mo.	76	6.6
4 mo.	43	3.7
5 to 6 mo.	30	2.6
7 to 9 mo.	19	1.6
10 to 12 mo.	9	0.8
13 to 18 mo.	9	0.8
19 to 24 mo.	15	1.3
2 to 4 yrs.	6	0.5
4 to 8 yrs.	5	0.4
8 to 16 yrs.	2	0.2
over 16 yrs.	5	0.4
Totals:	1,158	100.0

How can the distribution of lost service times be characterized? It is clear from Table 10 that there are exponential phenomena (long-tail distribution) associated with this data set. Over half of the incidents (58.5%) entailed 1 month or less of time lost. The substantial majority of the incidents—fully 81.1%—saw less than 3 months impact on the service life of the vessel. Yet 33 incidents (2.8%) caused more than 18 months of lost time, and 5 (0.4%) incidents took away

over 16 years of service life, which is half of the typical lives of the ships in the classes considered in this research (see Tables 1 to 5).

Given the uncertainty of many of the service time lost estimates, and the incompleteness of the database (many of the more minor incidents have surely gone undiscovered), it may be an exercise of marginal value to attempt to hypothesize and test for probability distribution fits to this data at this time. Initial tests indicate an exponential or inverse Gaussian form of distribution may be appropriate. Such detail is left for future analysis.

4.3 Analysis by ship category

Before discussing incident counts and lost time variability according to the category of ship, it provides useful perspective to examine service life directly for the various categories of ships. The average life of ships in this database, which includes both decommissioned and active vessels, is 23.7 years (28,985 ship-years, as of May 31, 2017, divided by 1,222 ships). If one considers only the 915 out-of-service vessels (decommissioned and lost), this value increases to 25.0 years.

Which categories of ships tend to live longer lives than others? Table 11 summarizes the service life statistics for all 915 out-of-service ships by category. The four WWII-era US Navy (USN) battleships top the list, but this statistic carries little relevance for today’s navies.

Table 11: Service life of out-of-service ships by ship category.

Ship Category	Retired Ships	Average Service Life (yrs)
Battleship	4	47.6
Littoral ship	66	30.0
Aircraft Carrier	48	27.6
Strategic Submarine	45	26.8
Destroyer	275	26.3
Conventional Sub	58	25.1
Oiler	18	25.1
Nuclear Submarine	108	24.6
Cruiser	65	22.5
Frigate	223	21.6
Other	5	16.7
Overall:	915	25.0

Littoral ships are second in longevity, at 30.0 years on average. They exist to project a land force ashore, so may be less heavily employed in a peacetime era. It might seem logical to extend the life span of more lightly employed vessels before replacing them with new ships.

Aircraft carriers are next at 27.6 years average service life. Their high cost alone would suggest extracting maximum life before replacement.

The three categories of submarines make an interesting comparison. Strategic submarines live a relatively gentle operational life in comparison to their tactical sisters. They too represent a higher capital investment, so one might not be surprised to see that their average life of 26.8 years is higher than the 25.1 and 24.6 values associated with conventional and nuclear attack submarines, respectively.

Destroyers lead the surface combatants in average life at 26.3 years, followed well back by cruisers and frigates at 22.5 and 21.6 years, respectively. The (traditionally) heavily armed cruisers and the (generally) smaller frigates seem to get replaced more quickly.

Replenishment oilers hit right near the overall average at 25.1 years. The 'others' category comprises a collection of 'one-off' experimental vessels (new propulsion, hybrid roles, etc.), so the observed short average life is no surprise.

Which individual ships served the longest? It is always interesting to see extremes. The list of ships in the database that exceeded 40 years of service life is presented in Table 12. A total of 26 ships achieved this level.

Note that the service life values in this database do not include any follow-on life with navies outside of the five considered here. Many of these ships were sold on to other navies around the world and continued serving to ages well into their 50s and 60s.

Note that seven of the ships listed in Table 12 are still serving as of May 31, 2017.

USN aircraft carriers top the list, headed by USS ENTERPRISE at 55.2 years. The list includes 7 carriers, all 4 battleships, and 8 littoral vessels of the US Navy. The table also lists 5 Royal Canadian Navy ships (2 replenishment oilers and 3 destroyers), including HMCS ATHABASKAN, which is still active but soon to be retired. The list also includes two Royal Navy replenishment oilers.

Table 12: Ships in the database that exceed 40 years of service life.

Ship	Hull No.	Type	Commissioned	Service Life (yrs)
				* Active
USS Enterprise	CVN 65	Aircraft Carrier	25-Nov-61	55.2
USS Lexington	CV 16	Aircraft Carrier	17-Feb-43	48.7
USS Kitty Hawk	CV 63	Aircraft Carrier	29-Apr-61	48.0
USS Missouri	BB 63	Battleship	11-Jun-44	47.7
USS New Jersey	BB 62	Battleship	23-May-43	47.7
USS Iowa	BB 61	Battleship	22-Feb-43	47.7
USS Wisconsin	BB 64	Battleship	16-Apr-44	47.5
USS Midway	CV 41	Aircraft Carrier	10-Sep-45	46.6
USS Blue Ridge	LCC 19	Amphib Command	14-Nov-70	46.5*
USS Mount Whitney	LCC 20	Amphib Command	16-Jan-71	46.4*
HMCS Preserver	AOR 510	Replenishment Oiler	30-Jul-70	46.2
USS Ponce	LPD 15	Amphib Tpt Dock	10-Jul-71	45.9*
USS Denver	LPD 9	Amphib Tpt Dock	26-Oct-68	45.8
HMCS Protecteur	AOR 509	Replenishment Oiler	30-Aug-69	45.7
HMCS Athabaskan	DDH 282	Guid Msl Destroyer	30-Sep-72	44.7*
USS Cleveland	LPD 7	Amphib Tpt Dock	21-Apr-67	44.4
USS Dubuque	LPD 8	Amphib Tpt Dock	1-Sep-67	43.8
HMS Gold Rover	A 271	Replenishment Oiler	22-Mar-74	43.2*
HMS Black Rover	A 273	Replenishment Oiler	23-Aug-74	42.8*
HMCS Iroquois	DDH 280	Guid Msl Destroyer	29-Jul-72	42.8
USS Coral Sea	CV 43	Aircraft Carrier	1-Oct-47	42.6
USS Nimitz	CVN 68	Aircraft Carrier	3-May-75	42.1*
USS Constellation	CV 64	Aircraft Carrier	17-Oct-61	41.8
USS Ogden	LPD 5	Amphib Tpt Dock	19-Jun-65	41.7
USS Austin	LPD 4	Amphib Tpt Dock	6-Feb-65	41.6
HMCS Algonquin	DDH 283	Guid Msl Destroyer	3-Nov-73	41.6

Do some nations tend to keep their fleets longer than others? While on the topic of ship age, it is an interesting side note to examine how average fleet longevity varies by nation. Table 13 presents the values for the five Navies considered in this analysis. Only completely retired fleets were considered, although Canada's Tribal-class destroyers were also included as HMCS ATHABASKAN is imminently retiring. Canada tops the list at 28.9 average years of service.

Table 13: Average ship life by nation.

Nation	No. of Fleets	No. of Ships	Average Life (yrs)
Canada	13	36	28.9
Australia	7	23	26.4
United States	57	586	26.0
United Kingdom	32	201	21.6
New Zealand	6	20	18.0

Are some types of naval vessels more prone to SLT incidents than others? Insights into this question can be gleaned directly from Table 14 below. A simple count of incidents would be misleading, as there are have been more ships of some types than others serving in these navies. Hence, the commissioning and decommissioning dates of each of the 1,222 ships have been used to calculate a service life value for each. For ships in active service, the time-in-service value was computed as of May 31, 2017. These ship-years (S-Y) of service are accumulated in Table 14.

The number of incidents and ship-months lost values in the table are accumulated from the database for each category of ship. These are normalized by the ship-years of service values to yield the values in the two right-most columns in the table. To present the calculations in perhaps a more useful form, the normalized incidents and ship-months lost values are presented in terms of averages over 30 years of ship life, a typical value that might be used for force structure planning purposes.

Table 14: Peacetime incidents and service time lost by ship category.

Ship Category	No. of Incidents	Ship Mo. Lost	Ship-Years of Service (S-Y)	Incidents per 30 S-Y	Months Lost per 30 S-Y
Aircraft Carrier	270	440	1590	5.1	8.3
Littoral Ship	120	209	2777	1.3	2.3
Surface Combatant	481	1678	16137	0.9	3.1
Submarine	277	1898	7420	1.1	7.7
Other	2	23	325	0.2	2.1
Oiler	8	154	737	0.3	6.3
Overall:	1158	4402	28985	1.2	4.6
Surface Combatants:					
Battleship	7	26	191	1.1	4.1
Cruiser	63	168	2056	0.9	2.5
Destroyer	265	1095	8292	1.0	4.0
Frigate	146	389	5599	0.8	2.1
Submarines:					
Conventional Sub	56	548	1607	1.0	10.2
Nuclear Sub	158	1177	4014	1.2	8.8
Strategic Sub	63	173	1799	1.1	2.9

Aircraft carriers are far and away more prone to SLT incidents than other categories. As the table indicates, they can expect 5.1 SLT incidents over a 30-year life, causing an expected 8.3 months of total lost service time over that life span. Carriers tend to be very active ships. Aircraft landings and operations in close proximity to other ships both increase the opportunity for mishaps. In comparison, all other combat vessels only can expect around 1 SLT incident over a 30-year life span.

Looking at all other combat vessels—battleships, cruisers, destroyers, frigates, littoral ships, and submarines—they are very consistent with each other in terms of frequency of SLT incidents, with the averages varying in a narrow range from 0.8 to 1.3 incidents per 30 years of service, with expected service time lost for surface ships ranging between 2 and 4 months over that life span. Littoral ships have the highest rate of occurrence at 1.3 mishaps per 30 ship-years. Perhaps working often in a shallow water environment adds slightly to the risk.

Although all submarine types can similarly expect about 1 mishap over their life span, the expected time lost statistics are not all that similar across the three types considered: conventional, nuclear (attack), and strategic (ballistic missile). The conventional subs can expect to lose 10 months of service over 30 years, but this is driven by only 5 past incidents, including the loss of HMS AFFRAY in 1951 and the recent Canadian experience with the Victoria-class submarines. The nuclear (non-strategic) sub class can expect to lose about 8 months of service, but this too is driven by several major losses in the 1960s of USS THRESHER and USS SCORPION, as well as the USS MIAMI sabotage incident in 2012. Strategic submarines, on the other hand, have not suffered any such significant mishaps and can expect to lose about 3 months of service over their lifetime, consistent with the (non-carrier) surface combatants.

4.4 Analysis by decade

From the immediate post-World War II era to the present, incredible changes have taken place within naval platforms, despite their relatively unchanged visual appearance. Nuclear energy has emerged as a power to be harnessed. Nuclear weapons and power plants had to be designed for safe operation and effective employment, and there is a learning curve with any new technology. Digital technology emerged and has grown exponentially, vastly improving the operating effectiveness, efficiency, and safety of naval vessels. With that, satellite navigation has immensely improved the accuracy and safety of maritime navigation. Fire suppression systems have become sophisticated, efficient and, in many ways, automated. All of this suggests that Navies should be safer today, and less likely to suffer peacetime SLT incidents than in the past.

Is the prospect of losing service life of a naval ship to peacetime incidents less likely today than it was yesterday? To examine this question, the 1,158 peacetime incidents were partitioned by decade, from the 1940s to the 2010s. The service life of each of the 1,222 ships was also partitioned by decade to provide appropriate normalization. See Table 15 below.

Table 15: Peacetime incidents and service time lost by decade.

Decade	Incidents	Service time lost (mo)	Time lost per incident (mo)	Ship-years of service	Incidents per ship-decade
1940s	25	92	3.68	729	0.34
1950s	102	441	4.32	2,222	0.46
1960s	217	1,255	5.78	4,456	0.49
1970s	295	899	3.05	5,695	0.52
1980s	262	587	2.24	5,752	0.46
1990s	79	231	2.92	4,367	0.18
2000s	122	433	3.55	3,403	0.36
2010s	56	464	8.29	2,362	0.24
	1,158	4,402	3.80	28,985	0.40

Note that the service time lost is attributed to the decade in which the incident occurred, and is not split into later decades if that ship had continued to be unavailable then.

The normalized incident rates are presented in the right-most column of Table 15 in terms of incidents *per ship-decade*. As this question is being addressed by decade, this seems natural. In the previous table, a 30-year (3-decade) normalization was used as that reflected a typical service

life target for force structure planning purposes. The normalized incident rates are usefully presented graphically, as per Figure 1 below.

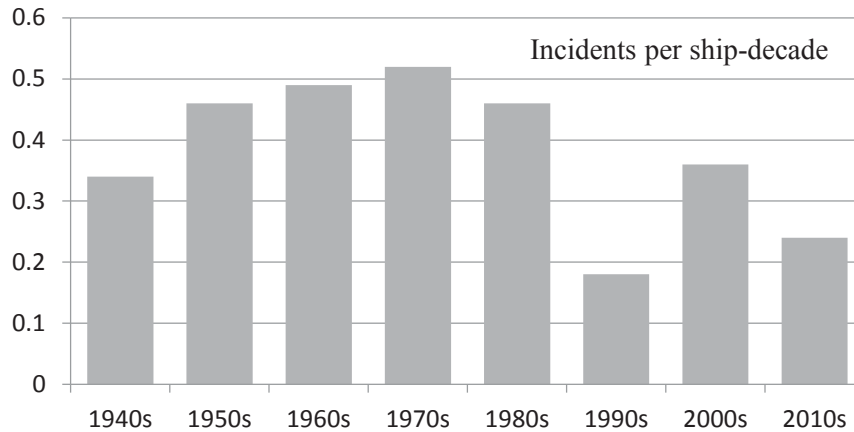


Figure 1: Peacetime incidents by decade.

The chart shows the incident rate increasing somewhat from the quiet, post-war era of the late 1940s² to a fairly steady value of around 0.5 incidents per ship-decade throughout the Cold War era. It then falls substantially in the 1990s to less than 0.2 incidents per ship-decade, rebounding in the 2000s and 2010s, but to levels well below the Cold War era highs.

This pattern is consistent with the learning phenomena associated with new technologies after WWII, and the steady, peace-time demands of the Cold War. The reduction in the 1990s is certainly coincident with the ‘peace dividend’, where the operational intensity (and fleet sizes) of the five Navies were reduced. All Navies saw increasing tempo following September 11, 2001 and the resulting increase in incident rates continues to the present.

The most relevant statistic pertaining to service time lost is simply time lost (in months) per incident in that decade. There is no particular reason to expect time lost per incident to vary much from decade to decade, and indeed the numbers in column 4 of Table 15 show most decades are fairly close to the average value of 3.80 months per incident.

However, there are two decades where the service time lost per incident is appreciably higher than that average—the 1960s and the 2010s. These high values are driven by several major incidents in these decades. For the 1960s, the high value of 5.78 months lost per incident can be attributed to the loss of submarines USS Thresher and USS Scorpion in the early days of nuclear-powered submarines, and the freak sinking of Her Majesty’s Australian Ship (HMAS) VOYAGEUR when it collided with the carrier HMAS MELBOURNE. The average is even higher in the 2010s, at 8.29 months lost per incident, due to the sabotage incident on submarine USS MIAMI, and a sequence of Royal Canadian Navy accidents involving HMCS CORNER BROOK, HMCS ALGONQUIN, and HMCS PROTECTEUR. The nature of these incidents does not suggest there is any underlying reason behind this apparent increasing trend.

² It is important to note here that the post-war decade of the 1940s only contains information for 1945-1949. As this is not a full decade of data, the reported rate may be unfairly skewed when compared to the other decades.

So to address the original question, yes, it was observed that incident rates have declined in the past 25 years to levels well below that of the Cold War era. It does appear that fewer incidents can be expected in the future than experienced in the past. The hope is that the observed high value of time lost per incident so far in the 2010s decade³ is a reflection of unfortunate circumstances more than anything.

³ Since the data was recorded as of May 30, 2017, this data for this decade is incomplete and the rate may change.

5 Summary and force structure planning insights

5.1 Summary

This research identified 1,222 front line naval vessels that served with the navies of Canada, Australia, New Zealand, the United Kingdom, and the United States since the end of World War II. Extensive research identified 1,254 incidents that caused, or could have reasonably expected to have caused, lost service time. Some were non-peace-time incidents, but 1,158 of the incidents were assessed as peacetime events.

On very rare occasions the ship was irretrievably sunk. This only occurred in peacetime five times. Three submarines (HMS AFFRAY in 1951, USS THRESHER in 1963, and USS SCORPION in 1968), one destroyer (HMAS VOYAGEUR in 1964), and one replenishment oiler (HMS ENNERDALE in 1970) were lost. The likelihood of losing a naval vessel in a peacetime incident before it formally retires can be estimated at 0.4% (5/1,222). Alternatively, this can be expressed as one ship lost for every 5,797 ship-years of service (28,985/5).

The primary measure captured for each of these incidents was *service time lost*, measured in months. The distribution of these times is extreme, with 58.5% of incidents causing 1 month or less of lost service time, yet 2.8% causing 18 months or more and 0.4% causing 16 years or more of lost service time. The average value was 3.80 months of service time lost per incident.

Considering the impact on operational scheduling, a repair time of 3 months or more might be considered sufficiently disruptive to planning. In this analysis, 19% of the peacetime incidents had a service time lost value (calculated or estimated) of 3 or more months.

This study identified 17 types of incidents, with *Collision* accounting for 31% of all peacetime incidents, followed by *Fire* at 17% and *Grounding* at 13%. Of these three, *Grounding* tends to do the most damage with an average of 5.2 months lost per incident. But the incident types that generated the most damage were *Terrorism* and *Sabotage* with over 10 months of lost time per incident. Notably, three incident types—*Aircraft crash*, *Weapon incident*, and *Nuclear incident*—all entailed much less than average damage to the ships.

Looking for differences between various categories of ships, it was noted that aircraft carriers suffer, by far, the most incidents, with an average of over 5 incidents expected over a 30-year ship life. All of the rest can expect about 1.2 service-life threatening incidents over their lifetime.

Temporal differences were also examined, and it was found that the incident rates during the Cold War era ran at more than double that of the ‘peace dividend’ decade of the 1990s, with the post-911 era seeing increased rates, but still at levels one-third below the Cold War era rates.

In terms of national difference, it was noted that Canada does keep its naval vessels longer than most, averaging 28.9 years of service for retired RCN ships, compared 26.4 years for RAN ships and 26.0 years for USN ships.

It may be of interest to compare these observed peacetime ship loss rates to those of wartime. In Annex B the loss rates of Royal Canadian Navy ships during the Second World War were

investigated. A total of 233 warships of corvette size or larger provided a combined 541.2 ship-years of service with the RCN during the six-year window of WWII, and 19 were lost. This works out to one ship lost for every 28.5 years of service, an increase of about 200 times over the peacetime rates.

5.2 Insights for maritime force structure planning

Over an estimated 30-year life span, a frontline naval vessel can expect to suffer 1.2 service-life threatening incidents. The expected lost service time over 30 years is 4.6 months. Only aircraft carriers can be expected to face risks above these levels.

Is the prospect of peacetime damage sufficient to impact the operational availability of the fleet? The answer is ‘yes’, to a certain degree. While each vessel in a 15 ship fleet is expected to lose, on average, 4.6 service months over a 30 year life span, the cumulative effect is an expected loss of over 5 years of ship service (or 1.3% of this total fleet’s service life). More investigation would be warranted as to the impact of the distribution of the lost service times across individual ship classes to determine the likelihood and severity of loss of operational availability.

Is the prospect of peacetime damage sufficient to warrant the purchase of additional platforms when new fleets are acquired? The answer must depend on the size of the fleets being acquired and the anticipated service life. To illustrate, assume a fleet size of 15 ships and an anticipated service life of 30 years. This research suggests there is about a 0.4% chance of a ship suffering a major incident which either sinks the ship or otherwise causes it to lose half of its expected service life or more. Hence, there is 94.2% chance (0.996 to the power of 15) that no ships will be lost over 30 years; or conversely, a 5.8% chance that one or more ships will be lost or suffer a major incident over the service life of the fleet. Is that risk, when also factoring in potentially declining incident rates, worth mitigating with the purchase of a 16th ship?

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Annex A List of maritime incidents

This annex contains a complete list of all 1,222 ships and 1,254 maritime incidents compiled by this research. The list is provided in digital form.

Annex B Royal Canadian Navy losses during WWII

It may be useful to put peacetime naval ship losses in perspective by comparing them to losses experienced in wartime. This annex summarizes the losses experienced by the Royal Canadian Navy during the Second World War, which is considered to have begun on 01 September 1939 and ended on 02 September 1945.

Only ship classes similar to those classes considered for this study were researched. A total of 233 ships were identified with service during WWII for the RCN in the five classes of aircraft carrier (2), cruiser (2), destroyer (37), frigate (69), and corvette (123). The RCN did not operate a submarine fleet during the war. Each ship's commissioning and decommissioning dates were used to calculate the number of ship-years served during the 6 year and 1 day window of WWII. Summing up, these 233 ships provided a total of 541.2 ship-years of service. All information was extracted online from Wikipedia, [3].

A total of 19 of the 233 ships were sunk or damaged beyond repair during the war: 10 corvettes, 6 destroyers, and 3 frigates. The losses were largely due to enemy action, with 13 ships struck by torpedoes from U-boats, one by air attack, and one by an underwater mine. The remaining four losses were due to collisions with other allied ships (3), and severe weather (1). Table B1 presents the details of the 19 losses.

Overall, the numbers show one ship lost for every 28.5 ship-years of war service. This rate was highest for the destroyer type at 1 loss per 18.0 ship-years. These rates are about 200 times higher than the peacetime loss rates estimated in this study.

Table B.1: RCN ships lost during WWII.

Ship Name	Type	Class	Date Comm	Date Lost	War Service (yrs)	Cause	Result
HMCS Fraser	Destroyer	C	17-Feb-37	25-Jun-40	0.82	Collision	Sunk
HMCS Margaree	Destroyer	D	06-Sep-40	22-Oct-40	0.13	Collision	Sunk
HMCS Levis	Corvette	Flower	16-May-41	19-Sep-41	0.34	Torpedoed	Sunk
HMCS Windflower	Corvette	Flower	15-May-41	07-Dec-41	0.56	Collision	Sunk
HMCS Spikenard	Corvette	Flower	15-May-41	11-Feb-42	0.74	Torpedoed	Sunk
HMCS Charlottetown	Corvette	Flower	13-Dec-41	11-Sep-42	0.74	Torpedoed	Sunk
HMCS Ottawa	Destroyer	C	15-Jun-38	14-Sep-42	3.04	Torpedoed	Sunk
HMCS Louisburg	Corvette	Flower	02-Oct-41	06-Feb-43	1.35	Air attack	Sunk
HMCS Weyburn	Corvette	Flower	26-Nov-41	22-Feb-43	1.24	Mine	Sunk
HMCS St Croix	Destroyer	Clemson	24-Sep-40	22-Sep-43	2.99	Torpedoed	Sunk
HMCS Athabaskan	Destroyer	Tribal	03-Feb-43	29-Apr-44	1.23	Torpedoed	Sunk
HMCS Valleyfield	Frigate	River	07-Dec-43	07-May-44	0.42	Torpedoed	Sunk
HMCS Regina	Corvette	Flower	22-Jan-42	08-Aug-44	2.54	Torpedoed	Sunk
HMCS Alberni	Corvette	Flower	04-Feb-41	21-Aug-44	3.54	Torpedoed	Sunk
HMCS Magog	Frigate	River	07-May-44	14-Oct-44	0.44	Torpedoed	Written off
HMCS Skeena	Destroyer	River	10-Jun-31	25-Oct-44	5.15	Weather	Sunk
HMCS Shawinigan	Corvette	Flower	19-Sep-41	25-Nov-44	3.18	Torpedoed	Sunk
HMCS Trentonian	Corvette	Flower	01-Dec-43	22-Feb-45	1.23	Torpedoed	Sunk
HMCS Teme	Frigate	River	28-Feb-44	29-Mar-45	1.08	Torpedoed	Written off

List of symbols/abbreviations/acronyms/initialisms

Amphib	Amphibious
Att	Attack
Aus	Australia
Avg	Average
Ball	Ballistic
Can	Canada
Commis.	Commissioned
DND	Department of National Defence
DRDC	Defence Research and Development Canada
Esc	Escort
gal	Gallons
Guid	Guided
Helo	Helicopter
HMAS	Her Majesty's Australian Ship
HMCS	Her Majesty's Canadian Ship
HMNZS	Her Majesty's New Zealand Ship
HMS	Her Majesty's Ship
ID	Identification
Incid	Incidents
M	Million
Mo.	Months
Msl	Missile
Nat.	Nationality
NATO	North Atlantic Treaty Organization
No.	Number
Nuc	Nuclear
NZ	New Zealand
Pow	Powered
RAN	Royal Australian Navy
RCN	Royal Canadian Navy

RN	Royal Navy
RNZN	Royal New Zealand Navy
RO-RO	Roll-On, Roll-Off
SLT	Service life threatening
S-Y	Ship-Years
Sub	Submarine
Tpt	Transport
UK	United Kingdom
USN	United States Navy
USS	United States Ship
US	United States
WWII	World War Two
yrs	Years

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13. **ABSTRACT** (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

This report presents a database of service life-threatening accidents/incidents involving the fighting ships from five navies—Canada, United Kingdom, United States, Australia, and New Zealand—since the end of the Second World War. The research identified 1,222 ships in these navies, including aircraft carriers, cruisers, destroyers, frigates, submarines, littoral ships, and replenishment oilers, which have delivered (to May 2017) a combined 28,985 years of service. The accidents/incidents research employed only open literature sources and identified 1,254 incidents. Each was categorized (a taxonomy of 17 incident types was employed), and the service time lost due to the incident was either calculated from established facts or estimated by the author based on known comparable incidents. The report also presents a summary analysis of the peacetime-only incidents, including a breakdown by incident type, ship category, and decade of occurrence. The full database is appended to the report in digital form. The intent of this research is to provide maritime force structure planners with data for statistical underpinnings in support of fleet sizing decisions.

Le présent rapport consiste en une description d'une base de données sur des accidents/incidents arrivés en service et mettant des vies en danger qui impliquaient des navires de combat de cinq marines—Canada, Royaume-Uni, États-Unis, Australie et Nouvelle-Zélande—depuis la fin de la Deuxième Guerre mondiale. La recherche couvre 1 222 navires de ces marines, y compris des porte-avions, des croiseurs, des destroyers, des frégates, des sous-marins, des navires côtiers et des ravitailleurs, qui comptent au total (en date de mai 2017) 28 985 années de service. La recherche sur les accidents/incidents n'a porté que sur des sources documentaires ouvertes et a permis de relever 1 254 incidents. L'auteur a catégorisé chacun d'entre eux (au moyen d'une taxonomie de 17 types d'incidents), puis a calculé le temps de service perdu en raison de l'incident à partir de faits établis ou d'estimations faites par l'auteur en fonction d'incidents comparables connus. Le rapport présente une analyse sommaire des incidents de temps de paix seulement, y compris une ventilation par type d'incident, par catégorie de navire et par la décennie où l'incident s'est produit. La base de données complète est jointe au rapport sous forme numérique. La recherche a pour but de fournir aux planificateurs des structures des forces maritimes des données avec lesquelles étayer leurs décisions en matière de taille de la flotte.

14. **KEYWORDS, DESCRIPTORS or IDENTIFIERS** (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g., Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Navy accidents; attrition; fleet sizing