

## Jump jets for the ADF?

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Is there a case for Australia to acquire F-35B Joint Strike Fighter short take-off, vertical landing (STOVL) aircraft to operate from the two new Canberra-class landing helicopter docks (LHDs)? The government has directed that this question be addressed in the development of the 2015 Defence White Paper.

This report is an independent assessment of the costs and potential benefits of such an acquisition. Reintroducing organic naval air power into the ADF would be a big strategic decision, and very complex and expensive, so it's important to have a clear view of the circumstances in which it might be beneficial enough to be worth pursuing. And it's important to be aware not only of the direct costs but also of the potential risks and opportunity costs. Overall, this report concludes that the benefits would be marginal at best, wouldn't be commensurate with the costs and other consequences for the ADF, and would potentially divert funding and attention from more valuable force structure enhancements.



An F-35B test aircraft lands vertically aboard the USS *Wasp* at night on 15 August 2013. © Lockheed Martin

## STOVL jets and their potential

Carrier-based aviation could provide a future government with greater military flexibility in regional and global contingencies. A carrier enables the projection of air power independently of land bases, thereby enhancing political freedom to manoeuvre without relying on the agreement of host nations. Proximity to the area of operations can also allow a more rapid response to tactical developments than might be available from land-based aircraft. Moreover, depending on circumstances, a carrier's mobility could provide a level of protection from detection and attack not available to fixed assets on the land.

Because of the potential to launch STOVL jets from the Canberra-class LHD's 'ski jump' deck configuration, it's tempting to see the LHD as a potential 'mini' aircraft carrier. With 27,000 tonnes displacement and 230 metres of deck, it will be Australia's biggest ever warship. But it will be much smaller than most traditional carriers, such as the US Navy's nuclear-powered 100,000-tonne Nimitz class and the future Ford class, the UK's future 65,000-tonne Queen Elizabeth class, France's nuclear 42,000-tonne *Charles de Gaulle*, and China's 59,000-tonne *Liaoning*. Those ships have been optimised for sustained fleet protection and land attack. That also applies, to a more limited degree, to dedicated 'light carriers' such as Italy's 30,000-tonne *Cavour* and the now decommissioned 22,000-tonne British *Invincible* class (see the appendix to this report for details).

In contrast, just like the 26,000-tonne Spanish *Juan Carlos I* LHD from which they're derived, the Canberra-class LHDs are designed as multi-role amphibious assault ships. Their primary purpose is to embark, disembark and support ground forces for a variety of missions. That also applies for much larger amphibious ships of the US Marine Corps, such as the 41,000-tonne *Wasp* class and the 45,000-tonne *America* class. Even though those ships will embark F-35Bs, their main role is to project and sustain land power from the sea.<sup>1</sup> However, the Spanish Navy also plans to use its LHD as an 'aircraft carrier', given its ability to embark STOVL aircraft, e.g. for fleet protection and power projection.

In principle, Australia's LHDs could be configured for the same purpose. But it's important to recognise that we still wouldn't play in the big league of aircraft carriers. The finite capacity of a Canberra-class LHD imposes constraints. The LHD couldn't carry its full complement of helicopters and amphibious troops with their vehicles and equipment and simultaneously deploy a useful number of STOVL aircraft and any additional support aircraft that might be needed. The latter could include helicopters for airborne early warning (which the ADF currently doesn't have), antisubmarine warfare and search and rescue, although conceivably some of the helicopters could be operated from other ships in company. In some respects, this ability to choose can be seen as evidence of flexibility, not as a constraint, but that misses the point: on any one operation, the more that an LHD embarked STOVL aircraft for air defence or ground attack, the less would be the remaining capacity for amphibious operations.

Currently, the ADF intends that each LHD will embark, transport and deploy about 1,200 personnel (along with their equipment and aviation units) using a range of helicopters and landing craft. This configuration is optimised for ADF amphibious operations and lodgements in permissive and low-intensity environments. Missions could include stabilisation operations in the South Pacific, non-combatant evacuation operations, and humanitarian assistance and disaster relief. Helicopters armed with Hellfire air-to-surface missiles could be used if there were limited threats to the disembarking force.

At the other end of the scale is the option to embark a maximum number of F-35Bs for fleet protection and force projection. Presumably, this configuration would be for more intense conflicts, either independently or as part of coalition operations. The flight deck should be able to accommodate from six to eight STOVL aircraft. If the hangar were used to the full extent, the ship could probably carry between 12 and 16 jump jets.<sup>2</sup> But the LHD would also need to embark one or two airborne early warning helicopters (at least) to support STOVL operations, thus reducing the number of F-35Bs. Furthermore, because of the relatively small number of STOVLs, the LHD would face challenges in generating enough F-35B sorties continuously to protect itself and ships in company against a capable adversary. The constrained range and weapons payload of the F-35B could also limit its effectiveness in land-attack, compared to the A and C variants of the Joint Strike Fighter.

Last, the LHD could potentially embark a mix of STOVL jets and helicopters to provide air cover for a landing amphibious force, to attack ground-based threats (such as mortar positions) or as a show of force to intimidate hostile elements. The LHD would

probably need to embark a minimum of four F-35Bs to enable the simultaneous deployment of two aircraft. While this would reduce the space for helicopters and storage facilities for amphibious operations, the ADF should still be able to embark a sizeable amphibious force. However, if the threat levels faced by the amphibious force in such contingencies were low, it's doubtful whether F-35Bs would really be needed.

## Direct and indirect costs

Carrier-based aviation would be a multibillion-dollar defence investment and would be likely to take more than a decade to develop because of the capability's complexity. There's also a need to consider risks associated with the F-35B program and opportunity costs in the future equipment program.

### Modifying the ship won't be enough

As built, the LHDs have been optimised for amphibious operations using helicopters and watercraft. They don't have the air traffic control, specialised maintenance facilities or storage for fuel and weaponry needed for STOVL operations. The flight deck would also require heat-resistant coating to deal with the heat generated by the F-35B's exhaust.<sup>3</sup> An informal estimate of the costs of modifying one LHD would be around \$500 million, although that figure would require confirmation.

Further, a decision to acquire F-35Bs could increase the pressure to get more ships and other supporting assets. A flexible 'part-time' jump jet capability where the LHDs are configured according to the specific mission sounds good in theory. However, it's hard to see how, with only two LHDs, the ADF could avoid compromising its ability to prepare adequately for both mission sets, let alone have at least one ship ready to deploy at any given time. If the goal were to use one LHD as a full-time power projection capability with the maximum number of STOVL aircraft while simultaneously retaining the amphibious component for the ADF, at least one more LHD (\$1.5 billion) and possibly another air warfare destroyer for protection (\$2 billion) would be needed. The ADF would also need to buy airborne early warning helicopters and more antisubmarine warfare helicopters to support the STOVL capability. All up, making the STOVL capability work would be likely to require considerably more money than that required to modify the LHDs and buy the jets.

### The F-35B: risky, expensive and less capable

Because of its stealth characteristics, advanced sensors, and range and payload, the F-35B will be more capable than the Harrier STOVL aircraft currently used by the US and others. The US Marine Corps plans to use it for amphibious assault against highly capable adversaries. However, the aircraft remains controversial because of technical problems and major cost overruns. The F-35B is also the most expensive Joint Strike Fighter variant. Table 1 shows the Pentagon's estimated 'flyaway' costs per unit once the full production rate has been reached.

**Table 1: US Department of Defense projected F-35 flyaway costs per unit (US\$ million, 2012)**

	Joint Strike Fighter variant		
	F-35A	F-35B	F-35C
Airframe	66.0	76.8	78.2
Engine	11.7	28.7	11.5
<b>Total</b>	<b>77.7</b>	<b>105.5</b>	<b>89.7</b>

Source: Jeremiah Gertler, *F-35 Joint Strike Fighter (JSF) Program*, Congressional Research Service, Washington DC, 29 April 2014, p. 17.

The flyaway cost excludes some acquisition costs (for example, facilities, initial spares, weapons, simulators and so on) and life-cycle costs. It's also based on assumptions about future inflation rates, production learning curves and numbers of aircraft sold. Even this conservative 'best case' figure means that the government would have to spend roughly \$5 billion for two

squadrons (18–24 aircraft) of F-35Bs, plus about another \$7 billion for through-life costs (over, say, a 25–30-year period). More accurate assessments of through-life costs (which are almost always underestimated) would need to take account of the very high technological complexity of *any* of the F-35 variants.

These are significant sums, both in absolute terms and in foregone opportunities to acquire other defence capabilities instead. One of the questions the government needs to answer is whether the F-35B acquisition would be at the expense of any of the Air Force's F-35As, or other critical capabilities that would add more value for the ADF than the STOVL option. That might include more capable future frigates, enhanced special forces, a capability for defence against ballistic missiles, or the V-22 Osprey helicopters, which could also be operated from the LHDs.

The ADF would also need to ensure that the Navy's focus on STOVL training did not come at the expense of other activities, particularly in the area of joint force training with the LHDs for amphibious operations. The potential for STOVL training to disrupt the ADF's emerging amphibious capability would be significant, not least because of the complexities of carrier operations and the time and effort required to develop skills and doctrine.

Last, modifying the LHDs would mean taking them out of service for quite some time, although the effects of that could be mitigated by making the modifications at the same time as scheduled refits or maintenance.

It should also be noted that the F-35B STOVL has a shorter combat range and a lighter weapons payload than the land-based F-35A or the conventional take-off F-35C carrier version (Table 2).

**Table 2: F-35 variants compared**

Variant	Range (internal fuel)	Combat radius (internal fuel)	Weapons payload	Standard internal weapons load
F-35A conventional take-off and landing	>1,200 nm / 2,200 km	>590 nm / 1,093 km	8,160 kg	25 mm GAU-22/A cannon 2 x AIM-120C air-to-air missiles 2 x 2,000 pound GBU-31 JDAM guided bombs
F-35B short take-off / vertical landing (STOVL)	>900 nm / 1,667 km	>450 nm / 833 km	6,800 kg	2 x AIM-120C air-to-air missiles 2 x 1,000 pound GBU-32 JDAM guided bombs
F-35C conventional carrier take-off and landing	>1,200 nm / 2,200 km	>600 nm / 1,100 km	8,160 kg	2 x AIM-120C air-to-air missiles 2 x 2,000 pound GBU-31 JDAM guided bombs

Source: Lockheed Martin Australia, <http://www.lockheedmartin.com.au/us/products/f35.html>

In addition, all F-35 variants are able to carry weapons and external fuel under their wings, although this adds drag and reduces stealth. Nevertheless, the F-35B couldn't carry the modern Norwegian Joint Strike Missile—which could become the standard missile for the F-35A and F-35C variants—because of size and mass considerations.<sup>4</sup>

## Where would it make sense?

What are the circumstances in which such a capability might be used? And could other capabilities achieve a similar or sufficient effect? The ADF's 'principal tasks', established over many years, provide a good analytical framework for assessing the potential utility of STOVL operations for Australia. Those tasks include operations in the defence of Australia, operations in the South Pacific, contingencies in Southeast Asia, and support of the US alliance in 'wider operations'.

As with all military operations, there would be occasions when the risk of serious loss would outweigh the benefit expected from the deployment. That is, vulnerabilities against different threat levels have to be taken into account. The LHDs would need to be protected from missile and torpedo attack. This means that, except in trivial cases, an LHD would need escorts such as air warfare destroyers and submarines to help protect it. Operations in high-threat environments would also require high levels of intelligence, surveillance and other support, including from land-based aircraft in at least some cases.

## Jump jets for the defence of Australia?

It's axiomatic that most, if not all, operations in the direct defence of Australia would be conducted from Australia, especially from the air bases across the north of the country. This is especially true of the protection of the Australian mainland. To the extent that coastal shipping might need protection and, specifically, defence against air attack, that would also be provided from the land. But such occasions would be rare, not least because of the infrastructure in place on the land, such as the all-weather railway from the south to Darwin and the steadily improving network of roads. If a high level of protection of coastal shipping were needed, it would be achieved in the first instance from dedicated land-based fighter aircraft, supported by in-flight refuelling, over-the-horizon radar, airborne early warning and control aircraft and Growler electronic warfare aircraft. Missile-equipped destroyers (air warfare destroyers) could also be used for air defence. While carrier-embarked STOVL aircraft could also make a contribution to the control of Australia's air and maritime approaches, it's hard to see how that further margin of capability would add value commensurate with the costs.

Strike operations would be conducted in the defence of Australia. The options here are wide. They would include land-based aircraft such as the F/A-18 Super Hornet and the F-35A, supported by in-flight refuelling and Growler aircraft. Other options include land-strike missiles launched by surface ships and submarines, the use of armed drones (UAVs), and perhaps in the future hypersonic missiles (if they could be justified as a priority in Australia's strategic circumstances). In sum, within the range of our land-based strike systems, the additional benefit from STOVL fighters seems to be marginal at best. There would also be the need to provide defence of the LHD and accompanying ships, especially against submarine and air attack. Although there could be situations in which the closer range to a target from an LHD could be an advantage, in most circumstances strategic strike, if properly planned, wouldn't need such a rapid response.

Proponents of a jump-jet capability might also argue that there could be operations in the direct defence of Australia that would require the ADF to operate beyond the combat radius of land-based strike aircraft. LHD-embarked F-35Bs could therefore give a forward-deployed joint task force an added layer of air defence, with options for anti-ship missions, land-strike and reconnaissance. However, beyond the range of land-based air cover, the protection of the maritime task force would become much more difficult and would require the continuous employment of at least half of the embarked STOVL aircraft for air defence tasks. This would leave a much reduced number for strike operations. While it's important to avoid circular arguments, it's also reasonable to assume that if the adversary were such as to merit strike operations against targets distant from Australia using the STOVL option, it would be quite capable of posing significant risk to the maritime strike force being used to project power in this way.

## STOVL for the South Pacific?

Australia has a key interest in the stability of the South Pacific and has often deployed the ADF to places such as Bougainville and the Solomon Islands to help defuse tension and to re-establish conditions in which disputes could be resolved peaceably. Similar operations are highly likely in the future and could well warrant the use of an LHD configured for amphibious operations.

However, on such operations Australia has so far used lethal force only sparingly, and experience shows that there's little if any need for high levels of combat air support. To the extent that aerial firepower might be needed, armed helicopters embarked on the LHDs should be sufficient. It requires a lot of imagination to argue that the security situation in the islands would require the use of sophisticated STOVL aircraft to get a satisfactory resolution. The South Pacific would have to be radically different from what it is today.

To at least a first approximation, such arguments apply to Papua New Guinea (PNG), too. Bougainville aside, the many challenges that PNG faces are more social and economic than military. The special case of the land border between PNG and Indonesia has been a cause for concern in the past, as West Papuan militants sought sanctuary on the PNG side of the border. But this issue and the associated tensions have been far better managed in recent years. Were Australia to contribute to the defence of PNG against

external armed attack (under the provisions of the 1992 Joint Declaration of Principles), Canberra would reasonably expect to be able to operate aircraft from land bases in that country (and in some cases to operate out of bases in northeastern Australia).

It's possible, however, to imagine circumstances in which STOVL aircraft operated from an LHD could make a useful tactical contribution; for example, by being positioned close to an area of operation, the jump jets might be able to respond more quickly than land-based aircraft. And there's scope to debate the respective vulnerabilities and risks: land bases require land forces to protect them from ground attack (including from special forces), the LHD needs protection against surface and submarine attack, and both require air defence. Clearly, the details and conclusions depend on the scenario and the capabilities and intent of the adversary against which Australia would be helping PNG defend itself. But, given the string of assumptions that need to be made to support the case, it would be drawing a very long bow to argue that PNG contingencies provide a reason for Australia to acquire STOVL aircraft for its LHDs.

## STOVL and Southeast Asia

The principle that Australia should seek to find its security 'in and with Asia, not against Asia' is also well established. What, then, might be the value of the STOVL option to Australia's ability to contribute to the security of that part of Asia closest to us? Identifying the circumstances in which Australia might want to conduct operations in the defence of Southeast Asia requires much speculation. Would it be a conflict or the threat of conflict between two or more ASEAN members? Could it be the prospect of operations by a major Asian power against one or more of the ASEAN countries? What would have to be at stake for Australia to make more than a modest contribution to the campaign? Would Australia itself be one of the countries under attack?

In any event, if the Australian Government decided to make a significant contribution, the ADF would reasonably expect to be able to operate land-based aircraft from the country whose own defensive efforts Australia would be supporting, or with whom we could come under common attack.<sup>5</sup> Just as for operations in support of PNG, it's difficult to conclude that such contingencies could justify the STOVL option. That's also because the ability of the hypothetical major power to attack the deployed ADF elements, including the LHDs, would need to be taken into consideration (as would the potential threat to the Australian homeland). Indeed, while all deployed forces would need protection, the consequences for a deployed LHD would be serious because of the trade-off between configurations of aircraft for air defence and strike made necessary by the ship's finite capacity. Again, depending on the assumptions about the scenario, the need for protection against submarine attack could be acute.

In sum, it's not clear what added operational value an STOVL capability would bring to the ADF in Southeast Asian contingencies.

## Supporting US alliance operations

Finally, consistent with Australia's US alliance, the LHD/STOVL capability could be used to support alliance operations in 'wider conflicts'. What are the scenarios in which Australia might contemplate the deployment of its 'mini-carrier' LHD and STOVL jets to support the US?

The worst case would probably be a US–China conflict. If that were to happen, any Australian Government would need to consider that China would most likely be in a position to pose a very high risk to forward-deployed ADF task groups, including the LHDs. The People's Liberation Army has embarked on a comprehensive modernisation program designed to prevent large surface ships, including US carriers, from operating near China. Investments in anti-ship ballistic and cruise missiles, submarines, and improved air defence systems provide the backbone of China's A2/AD (anti-access/area-denial) strategy. As a result, the US Navy is reconsidering the future of its carrier operations, including moving the ships further away from the reach of China's missiles.<sup>6</sup> The proliferation of precision-strike systems also has implications for amphibious operations. At a minimum, large carriers and amphibious assault ships will be pushed further out to sea. Consequently, the US Marines are examining how to project and sustain power ashore over greater distances.<sup>7</sup>

A forward-deployed Australian LHD and its accompanying naval task group in support of high-intensity US operations in maritime East Asia would therefore face very serious risks. Moreover, it's unclear how even a full complement of 12 to 16 STOVL aircraft would be an important contribution to a US coalition operation.<sup>8</sup> There'd be other, more effective ways for Australia to contribute to such a campaign, such as with submarines and land-based aircraft. As well, the operational demands of such contingencies would be very high, requiring intense (and costly) levels of training, including intensive joint training with the US. Before Australia tried to go down that path, it would need to be particularly confident that the US saw that this was the best way for the ADF to work with US forces. Operating LHDs with STOVL aircraft in North Asian contingencies would pose very high risks for the Australian forces, for little apparent military benefit for the US.

Outside the Asia-Pacific region, the ADF could be deployed alongside the US in the Middle East. A common argument for carrier-based aviation in that part of the world is that the use of foreign land-bases might not always be possible. However, a future scenario in which no Arab country (or Turkey or Israel) would offer the use of its air bases assumes a fundamentally transformed Middle East, united against US-led interventions. Indeed, the current conflicts in Iraq and Syria provide a more realistic model for future access to land bases. While Turkey has denied the US coalition the use of its air bases for strike operations, the United Arab Emirates, Jordan and Saudi Arabia offered to host allied fighter and support aircraft. It's prudent to assume that the Royal Australian Air Force would have access to land bases if Australia wanted to make a contribution to a future coalition air campaign in the region.

There's also the option of modifying the LHDs without acquiring the aircraft, in order to allow STOVL operations by US Marines during joint operations. The US Marine Corps often conducts bilateral carrier landings, usually using helicopters, to improve interoperability and cooperation with other nations. This could be a relatively low-cost investment and would provide the ADF with experience in STOVL operations without having to commit to a full-scale acquisition program. Nevertheless, the option would still run the risk of being tokenism. Questions of sovereignty would also have to be addressed.

## Conclusions

This paper has been written without the benefit of access to privileged information about costs and capability, and has not explored every conceivable contingency in which STOVL aircraft might be used. Nevertheless, the overall conclusion is clear: the cost-benefit analysis is not in favour of developing LHD/STOVL aviation for the ADF. The scenarios in which an LHD/STOVL capability would be realistically required *and* make an important operational impact are vague, at best. Therefore, the 2015 Defence White Paper should not announce a decision or intention to acquire jump jets for the ADF. There's no urgency to reach a decision next year. Furthermore, unless the government provides a compelling strategic narrative and significantly more money, there would be a real danger that the White Paper would raise unrealistic expectations about a much more muscular Australian strategic posture (including additional military capability).

Nevertheless, if the government is still interested in exploring STOVL, it should get an independent assessment of the potential costs and risks. Areas to be covered should include modifications to the two LHDs; the status of the F-35B program and 'best', 'medium' and 'worst' case costings (including operating costs); the likely impact on other ADF projects, including the amphibious capability; and the further costs for an additional LHD and escort ships. Opportunity costs in the future equipment program need particular consideration: there are likely to be better ways to spend the money that the STOVL option would require.

Finally, if carrier-based aviation were deemed necessary to support a much more muscular Australian military posture for regional and global deployments, the government should instead consider acquiring dedicated aircraft carriers to form the core of a serious naval battle group. However, as ASPI has shown in previous publications, the costs for such a capability would be considerable.<sup>9</sup> Even for major powers, a carrier capability is enormously complicated and expensive, and its operational utility could become increasingly contested with advances in warfighting technology.

## Appendix: Aircraft carriers and large amphibious ships

Country	Class	Tonnage (full displacement)	Under construction	Planned	Role	Remarks
United States	10 Nimitz-class carriers (nuclear powered)	Approx. 97,000 tonnes	Gerald R Ford class (100,000 tonnes)	2 x Gerald R Ford class	Aircraft carriers	
	8 Wasp-class LHDs	44,000 tonnes	America-class (45,600 tonnes)	11 America-class	Amphibious assault	America class to replace Wasp class
India	INS <i>Viraat</i> (to be decommissioned in 2017)	28,700 tonnes	INS <i>Vikrant</i> (40,000 tonnes)	INS <i>Vishal</i> (65,000 tonnes)	Aircraft carrier	INS <i>Vishal</i> could be nuclear powered carrier with catapult launch
	INS <i>Vikramaditya</i>	45,400 tonnes				
China	<i>Liaoning</i> (Admiral Kuznetsov class)	59,000 tonnes	First Chinese-designed carrier	Possibly 3	Aircraft carrier	
France	<i>Charles de Gaulle</i> (nuclear powered)	42,000 tonnes	–	–	Aircraft carrier	Joint carrier operation with UK planned
Russia	<i>Admiral Kuznetsov</i>	55,200 tonnes	–	Possibly 1	Heavy aircraft-carrying cruiser	Plans for advanced carrier in the 2030s
Brazil	<i>Sao Paulo</i> (Clemenceau class)	32,800 tonnes	–	–	Aircraft carrier	Built in 1960, currently under maintenance
Thailand	HTMS <i>Chakri Naruebet</i>	11,500 tonnes	–	–	Disaster relief	
United Kingdom	Queen Elizabeth class (HMS <i>Queen Elizabeth</i> )	70,000 tonnes	HMS <i>Prince of Wales</i>	–	Aircraft carrier	IOC for HMS <i>Queen Elizabeth</i> expected by 2020
Italy	<i>Giuseppe Garibaldi</i>	13,850 tonnes	–	–	Light aircraft carrier	
	<i>Cavour</i>	30,000 tonnes	–	–	Light aircraft carrier	Plans to acquire F-35Bs for the <i>Cavour</i>
Spain	<i>Juan Carlos I</i> LHD	26,000 tonnes	–	–	Multi-purpose amphibious assault	Plans to operate F-35Bs
Australia	Canberra-class LHD	27,500 tonnes	Canberra	Adelaide	Multi-purpose amphibious assault	
Japan	Izumo-class helicopter destroyer (DDH)	27,000 tonnes	One additional Izumo class	–	Primarily used for anti-submarine warfare	No indication of plans to operate STOVL aircraft

In addition, South Korea is considering equipping the second ship of the Dokdo-class landing platform helicopter ships with a 'ski-ramp' for possible STOVL operations. In the long term, the South Korean navy plans to build two 30,000-tonne light aircraft carriers between 2028 and 2036. Similarly to Australia, Turkey is building an LHD based on the *Juan Carlos* design in cooperation with Navantia.

## Notes

- 1 Of course, the US Marine Corps can rely for critical support on the US Navy's much larger aircraft carriers.
- 2 The Spanish Navy claims that its *Juan Carlos* LHD could carry up to 10 or 12 F-35B or AV-8B STOVL aircraft plus a similar number of helicopters in its aircraft carrier configuration. This report's more conservative estimate of the Canberra class's ability to embark STOVL aircraft and helicopters is based on the Royal Australian Navy's description of the ship's helicopter configurations.
- 3 The US Navy has yet to find a 'cost-effective solution' for a heat-resistant deck coating. See, for example, Carlo Munoz, 'SNA 2014: Heat from F-35, MV-22 continue to plague big deck amphibis', *USNI News*, 15 January 2014, <http://news.usni.org/2014/01/15/sna-2014-heat-f-35-mv-22-continue-plague-big-deck-amphibs>.
- 4 Colin Clark, 'Norway's Joint Strike Missile tempts Aussies; Raytheon likes it too', *BreakingDefense.com*, 16 July 2014, <http://breakingdefense.com/2014/07/norway-joint-strike-missile/>.
- 5 The success of such collaboration would be greatly helped by having already established the habit of close cooperation with countries such as Indonesia, Singapore and Malaysia.
- 6 Ronald O'Rourke, *China naval modernization: implications for U.S. Navy capabilities—background and issues for Congress*, Congressional Research Service, 8 September 2014, p. 52.
- 7 Kris Osborn, 'New threats change amphibious assault strategy', *DoD Buzz*, 28 August 2014, [www.dodbuzz.com/2014/08/28/new-threats-change-amphibious-assault-strategy/](http://www.dodbuzz.com/2014/08/28/new-threats-change-amphibious-assault-strategy/).
- 8 In evidence to the House of Commons Select Committee on Defence in November 2004, Admiral Sir Alan West said that the capacity of the Queen Elizabeth-class carriers to embark up to 36 Joint Strike Fighters was based in part on having the 'same sort of clout' as one of the US carriers. UK Parliament Committee on Defence, 'Examination of witnesses (questions 540–559)', 24 November 2004, [www.publications.parliament.uk/pa/cm200405/cmselect/cmdfence/45/4112404.htm](http://www.publications.parliament.uk/pa/cm200405/cmselect/cmdfence/45/4112404.htm).
- 9 Mark Thomson, Andrew Davies, 'Strategic choices: defending Australia in the 21st century', *ASPI Strategic Insights* 45, December 2008, pp. 22–23.

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