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Resilient Aerial Refueling:

Safeguarding the US Military's Global Reach

Discussion of K(C)-Z design considerations with with NDIA Aircraft Survivability Workshop

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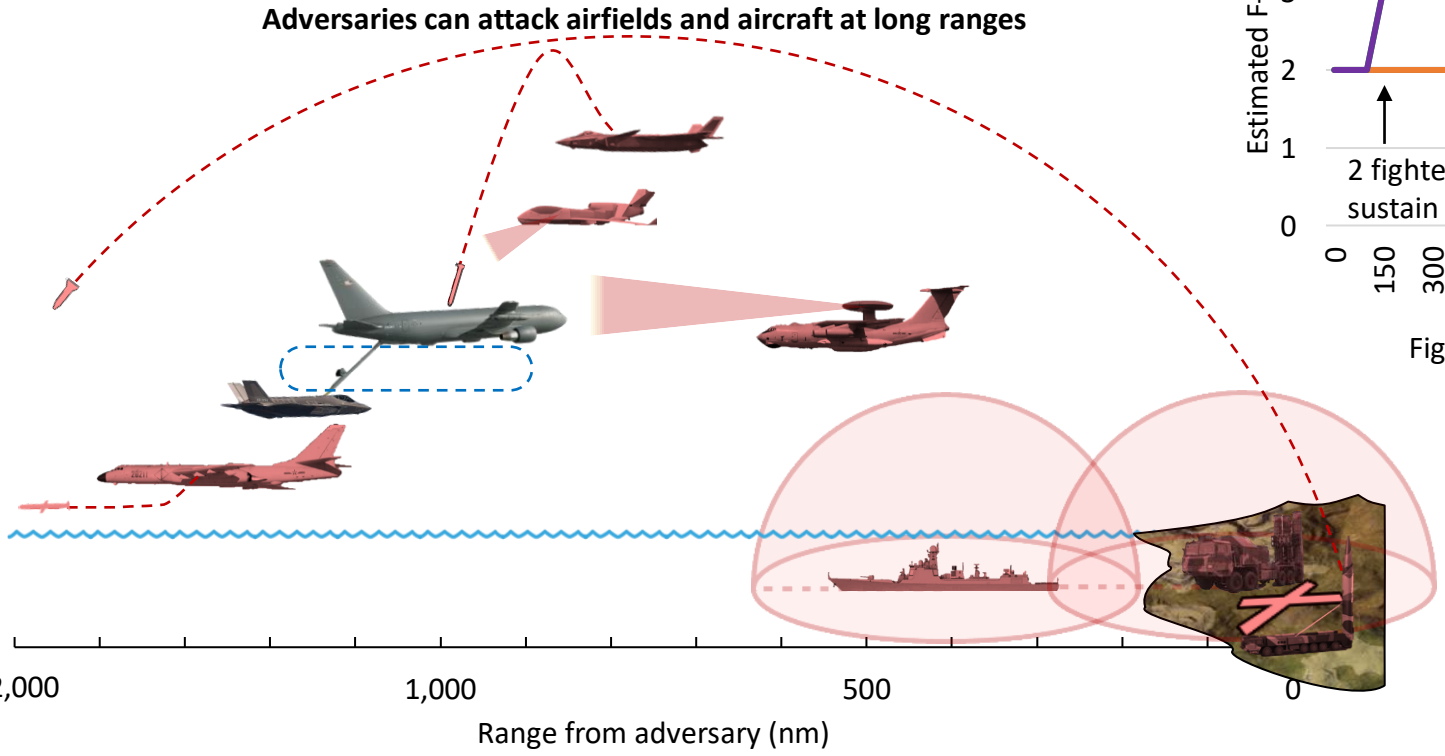
Key findings

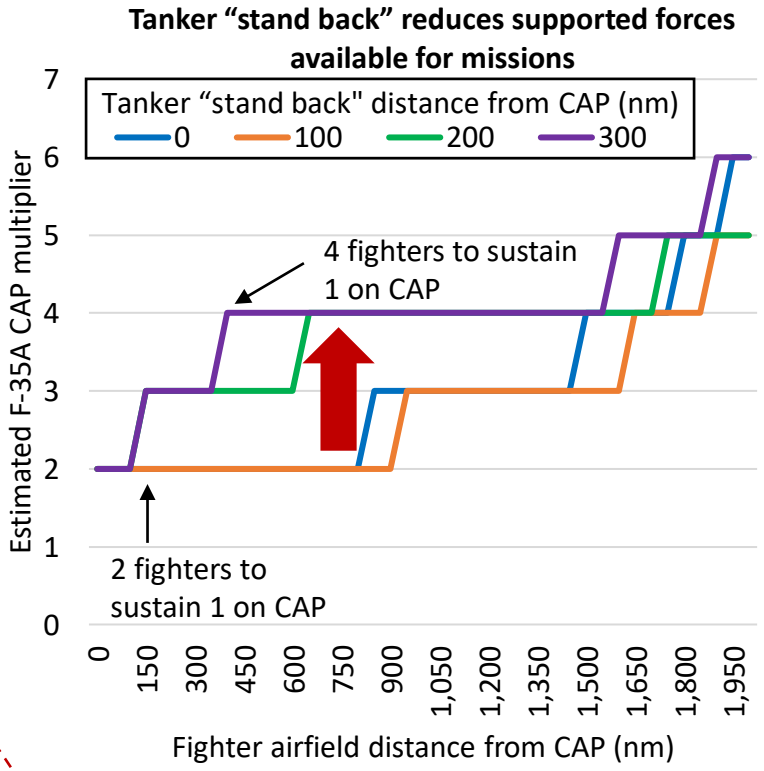
- **The current US aerial refueling architecture of surface infrastructure, command, control, and communications (C3), and tankers is inadequate to counter the threat posed by China and support new airpower concepts.**
- **DoD needs new aerial refueling concepts and capabilities to allow the Joint Force to conduct operations in a more effective, distributed, and sustained manner.**
  - The most cost-effective improvements are in the areas of surface infrastructure and C3.
- **Evolved USAF tanker fleet can be more operationally effective and fiscally sustainable by:**
  - Enhancing the survivability of some current tankers with new C3 and self-defense capabilities.
  - Procuring a Bridge Tanker force that provides high-capacity offload at range.
  - Accelerating development and fielding of a new design, highly efficient medium-sized tanker, referred to as Advanced Air Refueling tanker or K-Z/KC-Z.

By acting decisively, USAF can boost its aerial refueling capacity in the Indo-Pacific by 63% within a decade and overcome budgetary headwinds to transition to a more effective future force within 15 years.

Threats to refueling can degrade or constrain operations

- **Attrition to aircraft on the ground and in the air**
- **Damage to surface architecture**
- **Virtual attrition imposed by threats to C3 and changes in operations**





Proposed attributes of the future aerial refueling architecture

Changes to tankers

Existing tankers (Bridge Tanker)

KC-46A

Lockheed Martin Next Generation Tanker (LMXT) (A330 MRTT)

New design tanker concepts (K-Z)

Very low observable flying wing

Low observable flying wing or blended/hybrid wing body

Lightweight, efficient tanker

Very small UAS tanker

Design concepts can be scaled to medium or small-capacity tankers

USAF can field new tankers to complement KC-46A.

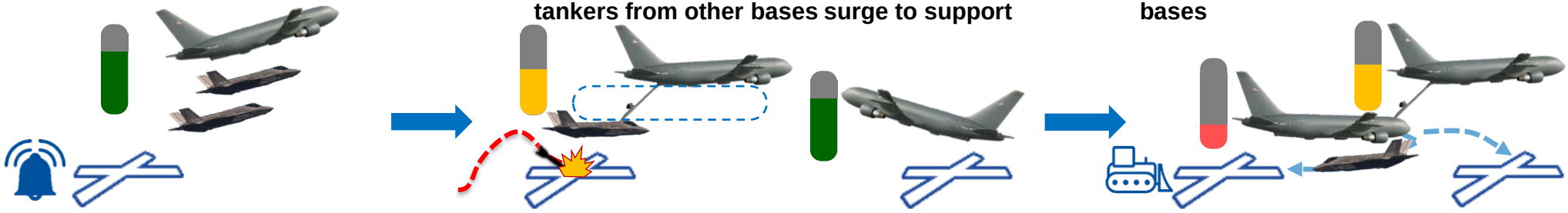
Force extension provides great operational value

1) Force extension: mutual base support tanking

Aircraft launch on warning of attack

Tankers sustain orbiting aircraft; tankers from other bases surge to support

Aircraft recover at own or divert bases



2) Force extension: tanker extend/consolidation tanking

Multiple tankers take-off

One tanker refuels others

Full tankers continue mission

3) Force extension: shuttle/yo-yo tanking

Larger tanker refuels smaller tanker outside contested area

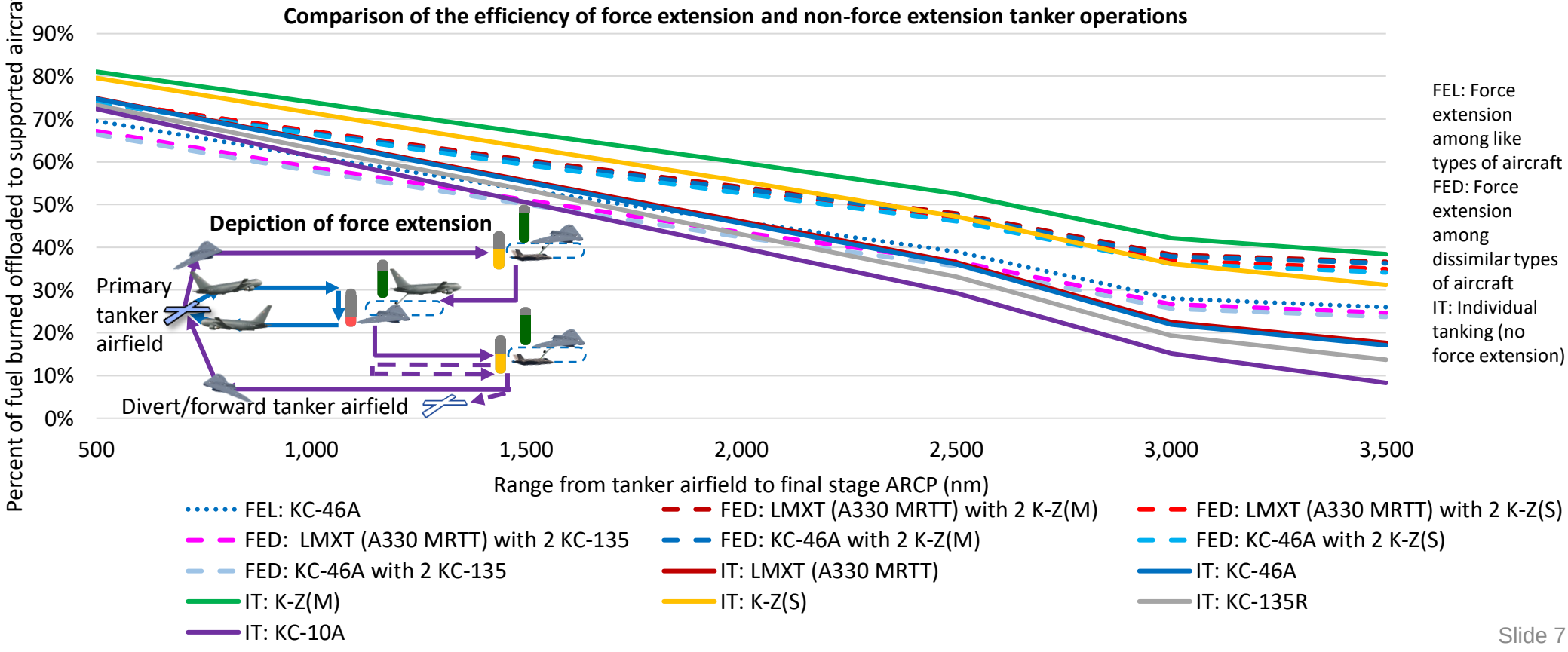
Smaller tanker refuels aircraft in contested area

Aircraft conduct operations in contested area

Force extension confers ability to conduct long-range operations, tactical flexibility, and resilience to force.

However, tanker designs should not depend on force extension

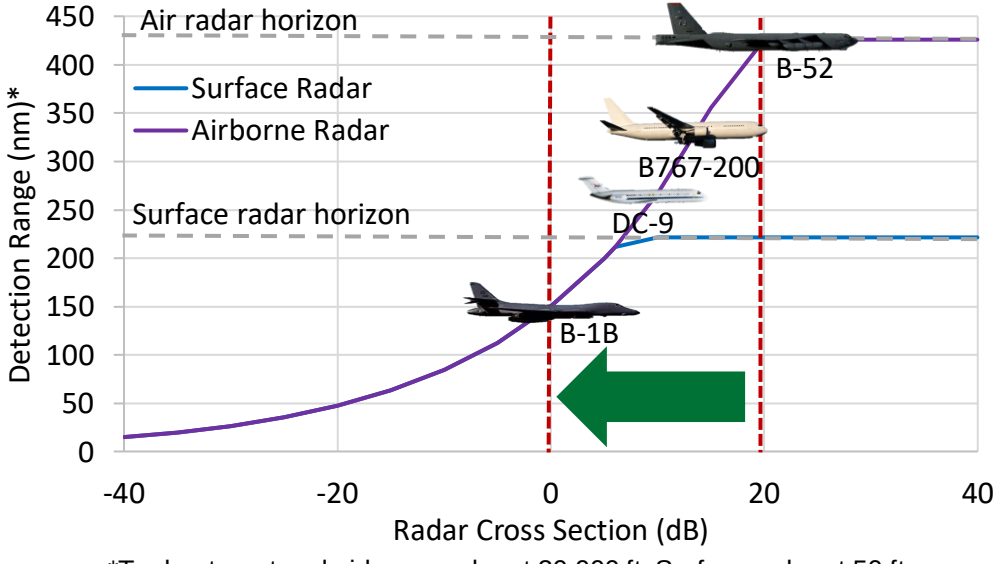
- **Multi-stage delivery of fuel is in most cases less efficient than single-stage deliveries.**
  - Applies across aircraft type mixes and most ARCP ranges
  - Large/small combinations require too many tankers in the cycle and inefficiently use ramp space.
- **Future tanker designs should incorporate universal receiver capability but should not be optimized for force extension.**



Tanker survivability can be enhanced at moderate cost

- **Tanker survivability should focus on low-cost, high impact options to reduce signatures and boost defenses, while decreasing receiver standoff distance from ARCP.**
  - Reduction in size of future tanker and shaping best practices could reduce effective signature at moderate cost; C3 upgrades and soft and hardkill countermeasures could grant significant protection
- **Very low observable tanker would be expensive to develop and procure.**
  - Costs may foreclose other investments in aerial refueling enterprise
  - Tanking will likely be a high signature event that would raise signatures

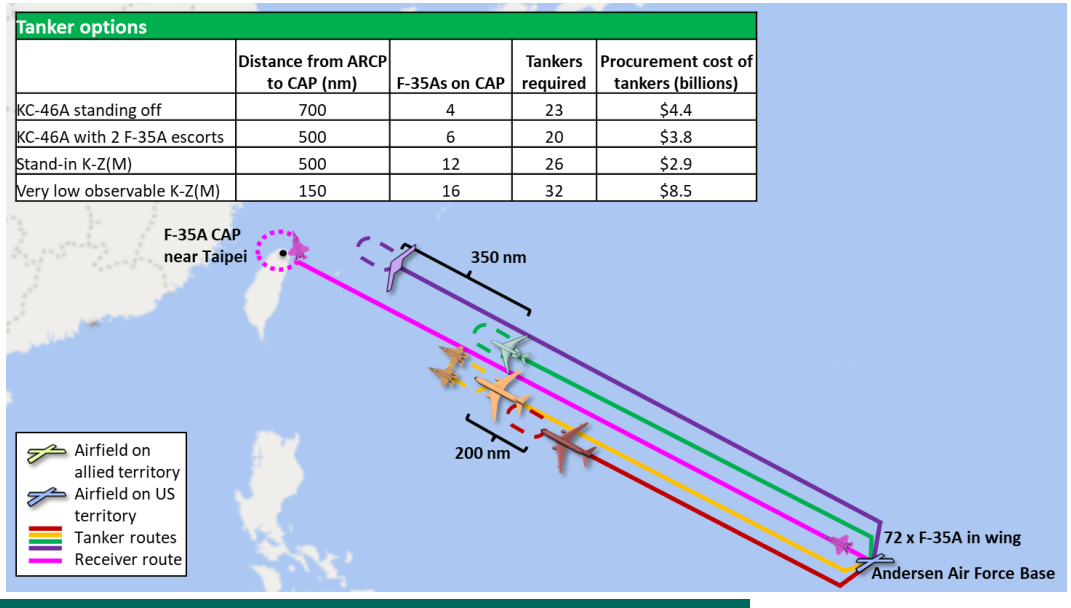
Estimated radar detection range of aircraft



*Tanker target and airborne radar at 30,000 ft. Surface radar at 50 ft.

Impact of tanker options on operational performance and cost

Tanker options	Distance from ARCP to CAP (nm)	F-35As on CAP	Tankers required	Procurement cost of tankers (billions)
KC-46A standing off	700	4	23	$4.4
KC-46A with 2 F-35A escorts	500	6	20	$3.8
Stand-in K-Z(M)	500	12	26	$2.9
Very low observable K-Z(M)	150	16	32	$8.5



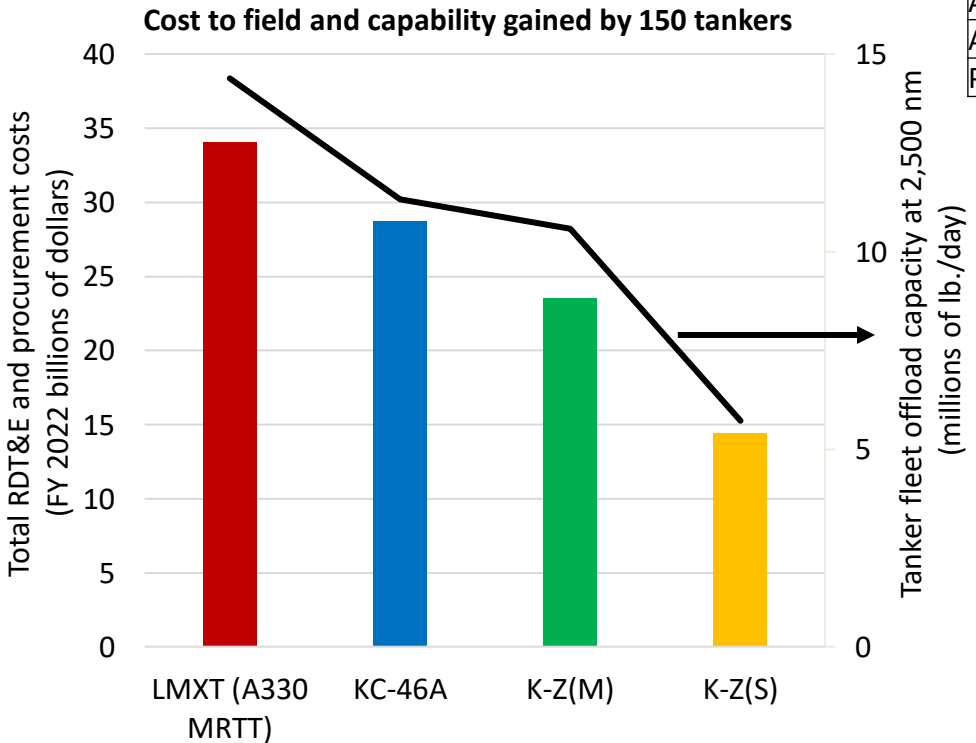
Stand-in tanker provides major tactical value at moderate cost.

New design tankers can be economically fielded

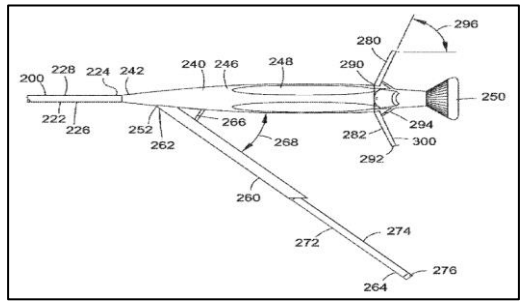
- **RDT&E costs affect procurement but are not determinative.**
- **By pursuing a moderate cost K-Z(M) design, USAF can develop and mature new self-defense, automation, autonomy, and boom technologies for current and K-Z tankers.**

Potential tanker fleet size based on spending over a decade ten times PB 2022 tanker procurement costs

Estimates	LMXT (A330 MRTT)	KC-46A	K-Z(M)	K-Z(S)
Total budget ($B)	**23.8**	**23.8**	**23.8**	**23.8**
Additional RDT&E costs ($B)	**0.28**	**N/A**	**6.93**	**4.62**
Procurement budget for tankers ($B)	**23.52**	**23.8**	**16.87**	**19.18**
Tanker cost per pound ($)	**848**	**938**	**1,164**	**931**
Aircraft APUC ($m)	**225**	**191**	**111**	**65**
Aircraft annual O&S cost ($m)	**18.11**	**16.97**	**10.93**	**9.63**
Potential fleet size	**104**	**124**	**152**	**294**



Airbus' Automatic Air-to-Air Refueling system on an A330 MRTT refueling a Portuguese Air Force F-16



Boeing patent for hybrid boom/drogue design

Conclusions

- **Enhancing the capacity and robustness of surface architecture should be a top priority for DoD.**
- **C3 improvements can greatly improve operational efficiency and effectiveness.**
- **Bridge Tanker force should provide high-capacity offload at range and pave the way to evolve the tanker fleet.**
- **Small or very small tankers are not good fits for USAF requirements.**
- **USAF needs K-Z (or KC-Z) that is efficient in terms of fuel consumption, ramp space, and lifecycle cost and is capable of offloading fuel at range, including in slightly contested environments.**

With decisive cross-portfolio trades, USAF can start to swiftly transition this decade to a resilient force that is more operationally effective and fiscally sustainable.

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Discussion

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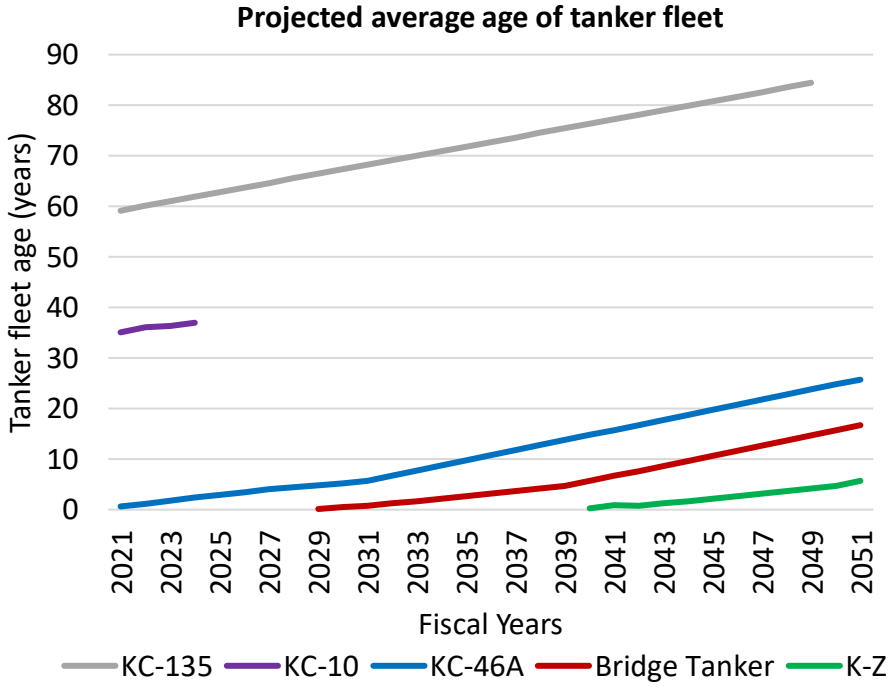
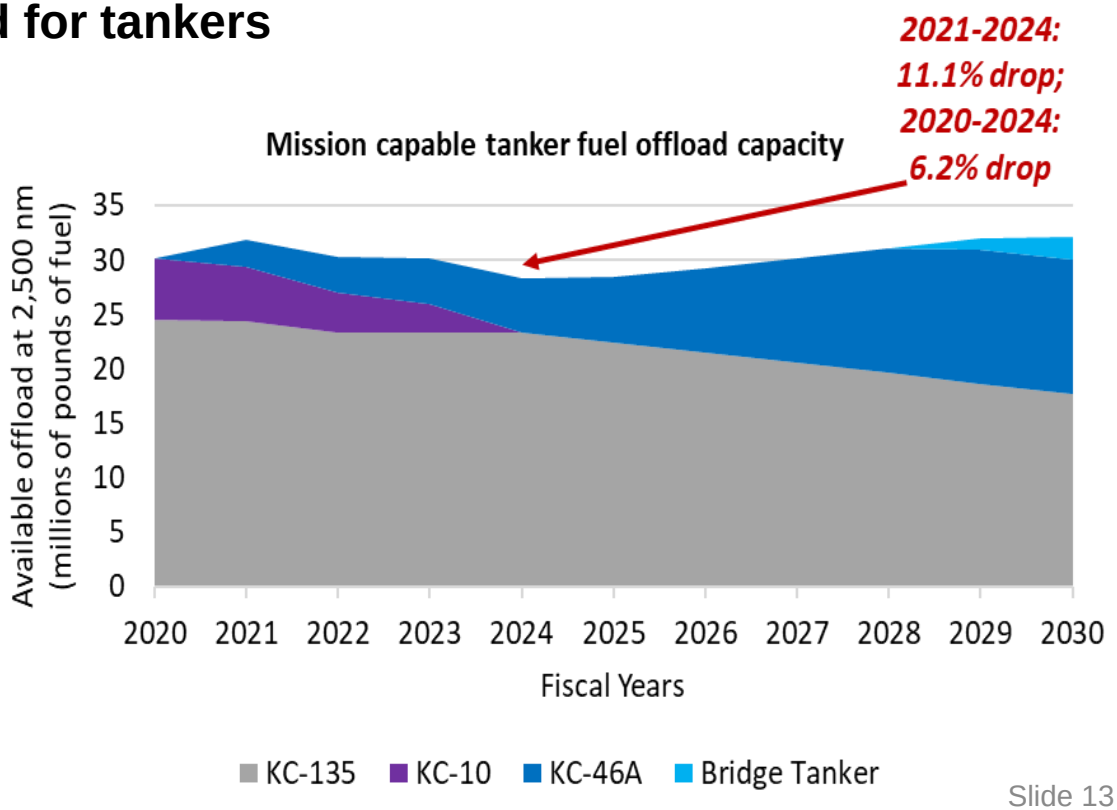
Aerial refueling reference slides

DoD concerns regarding aerial refueling force are growing

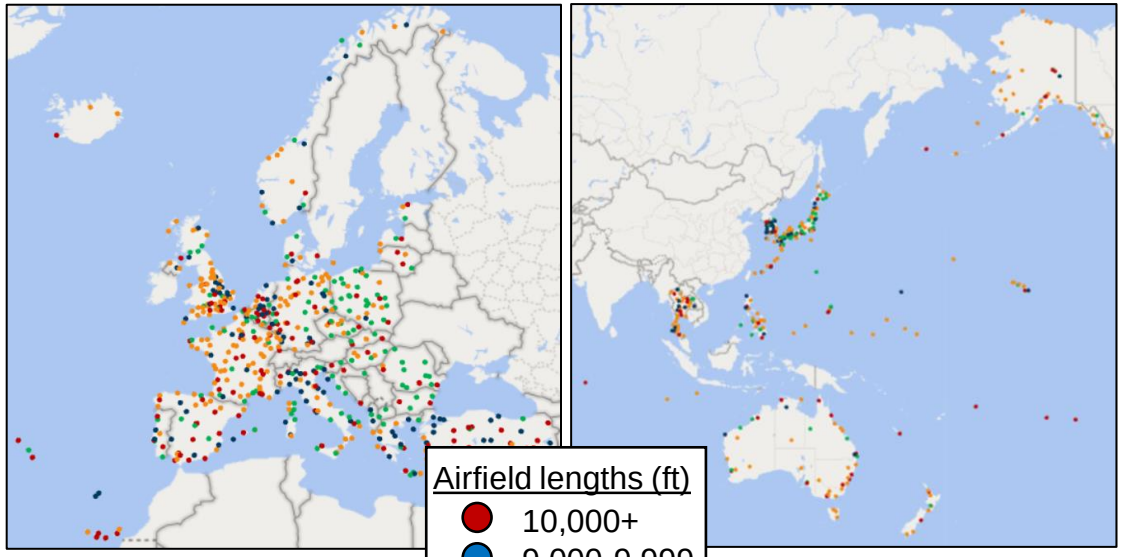
- **Aging, expensive to operate tanker fleet**
- **Tanker force faces straining tempo and deepening capacity gap, aggravated by delays in fielding KC-46A**
- **Higher combatant commander demand for tankers**





Refueling operations limited by access to suitable airfields and fuel

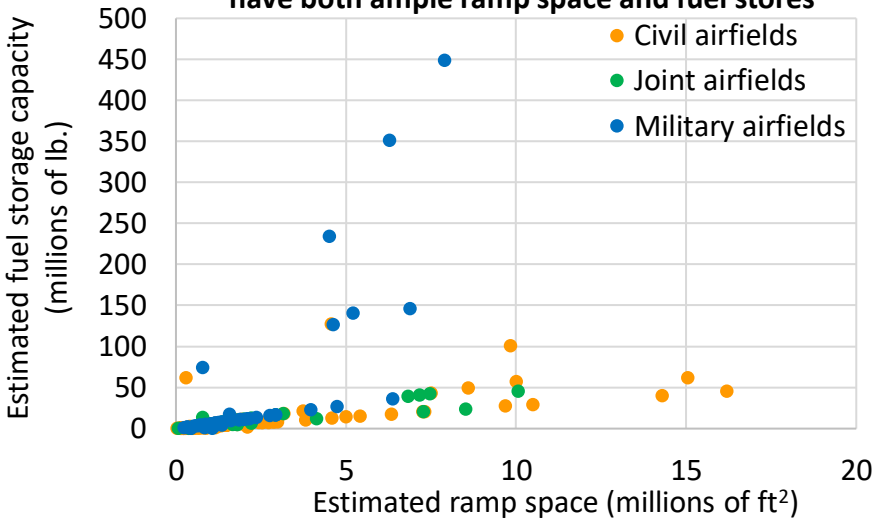
- **Lack of suitable airfields a major limitation to aerial refueling operations**
  - Combination of airfield runway length and firmness, apron space and firmness, fuel storage, and access to fuel distribution.
  - Particularly acute in the Indo-Pacific
- **Fuel storage gaps and dearth of distribution systems**



553 airfields in NATO countries in Europe

279 airfields in US and ally territory in Pacific and Indian Oceans

Relatively few airfields in Indo-Pacific have both ample ramp space and fuel stores



Laydown of potential airfields used by tankers in a conflict with the PRC

New concepts and capabilities are increasing demand for aerial refueling

- **Joint Force distribution across and within theaters**
  - ACE, Adaptive Basing
  - DMO, EABO, MDO
- **Longer-range and more dynamic operations**
  - High tanking demand across scenario types
- **New platforms capable of aerial refueling**
  - P-8A and E-2D
  - Planned MQ-25A buy enables recovery and mission tanking, but CVWs may require equal or greater USAF tanking support due to increased CVN standoff distance.

USAF F-15s practice rapid refueling in support of ACE

RAAF KC-30 refueling USN P-8A

MQ-25 test asset refuels a US Navy F/A-18F fighter

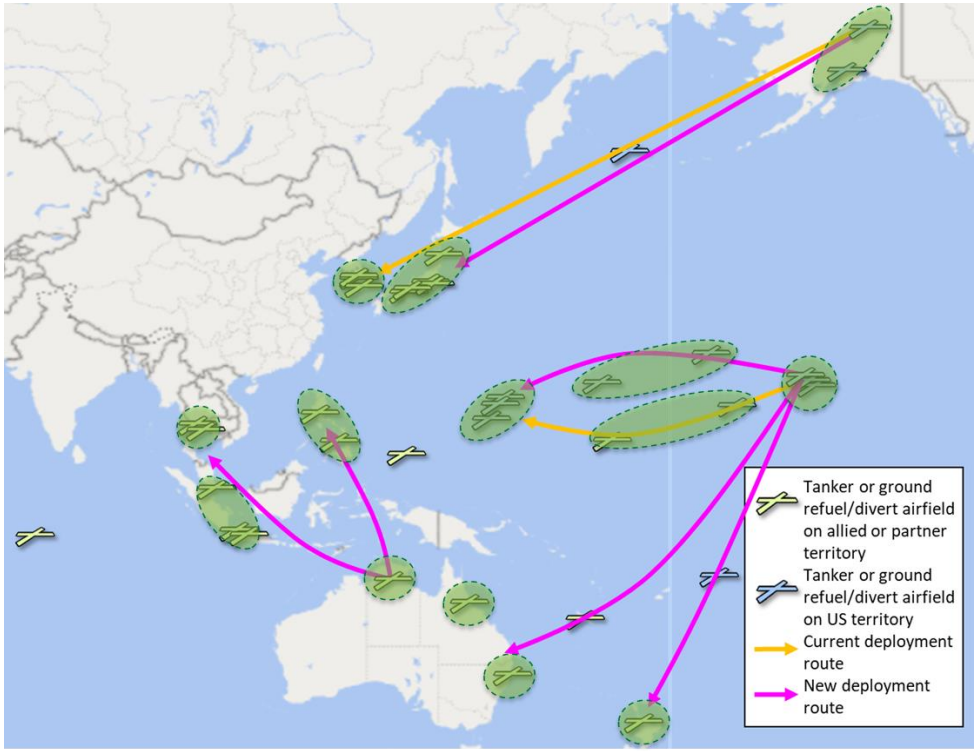
Study assessed enterprise using scenarios and CONOPS

Wide range of demands necessitate scalable and sustainable aerial refueling force.

Changes to the surface architecture: airfields

- **Gain access to mutually-supportive clusters of military and civil airfields at different distances**
- **Establish multiple, redundant paths to deploy and employ aircraft**

Potential redundant deployment paths and clusters of tanker or divert airfields

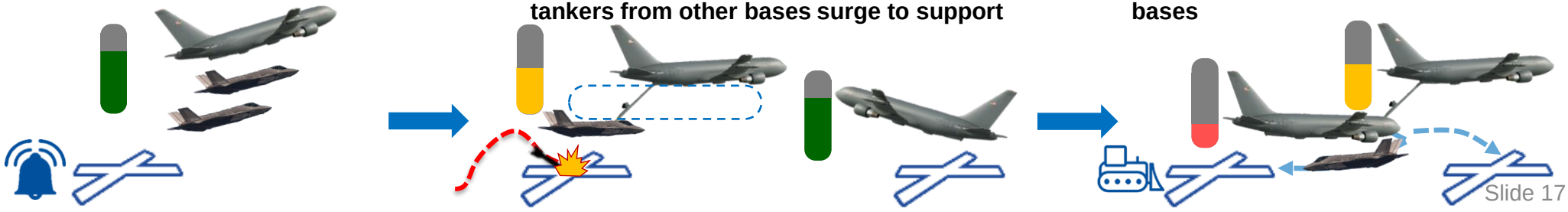


Mutual base support tanking

Aircraft launch on warning of attack

Tankers sustain orbiting aircraft; tankers from other bases surge to support

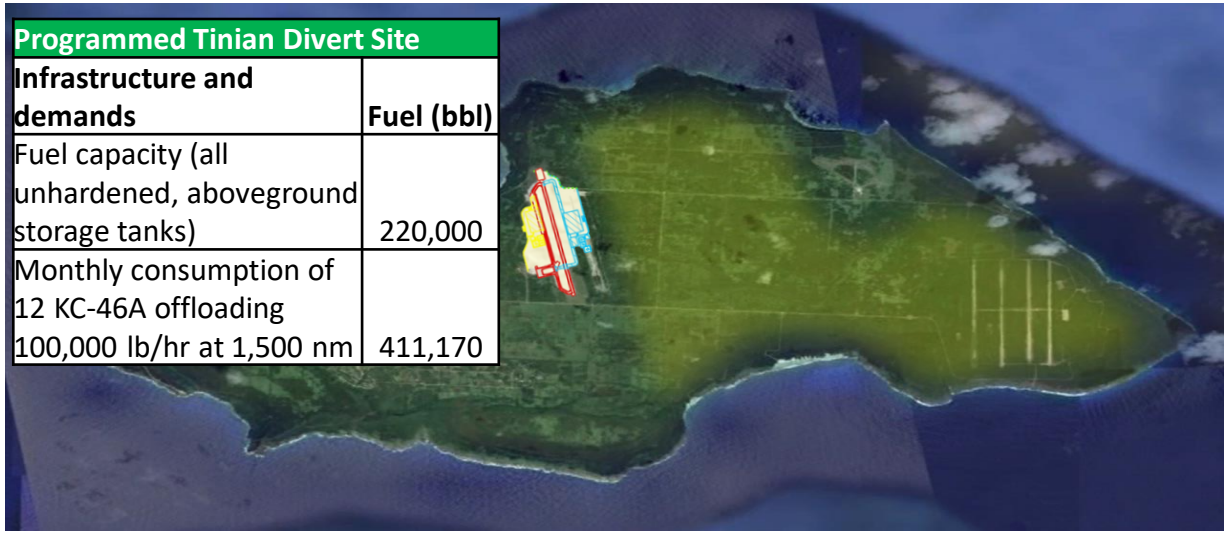
Aircraft recover at own or divert bases



Changes to the surface architecture: fuel and defenses

- **Expand hardened fuel stores and ramp space at airfields suitable for tankers**
- **Field bulk fuel distribution capabilities**
- **Deploy counter-ISR and air and missile defense systems**

Programmed Tinian Divert Site	
Infrastructure and demands	**Fuel (bbl)**
Fuel capacity (all unhardened, aboveground storage tanks)	220,000
Monthly consumption of 12 KC-46A offloading 100,000 lb/hr at 1,500 nm	411,170

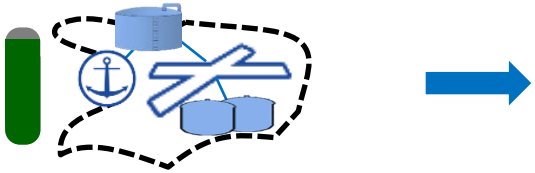


Current DoD plans in Tinian underutilize critical North Field runways by turning part of them into mortar ranges

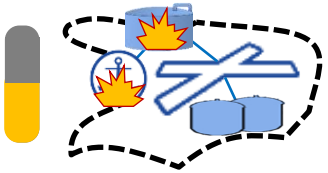
US-flag tug and barge deliver fuel over the shore in Alaska

Assured bulk fuel distribution

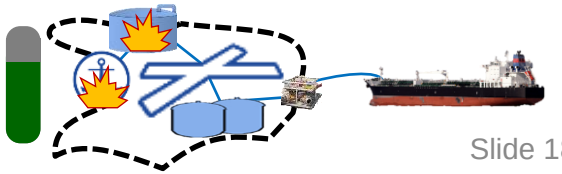
Resilient surface fuel architecture challenges adversary targeting



Underground fuel tanks provide fuel to base despite attacks to aboveground tanks and port

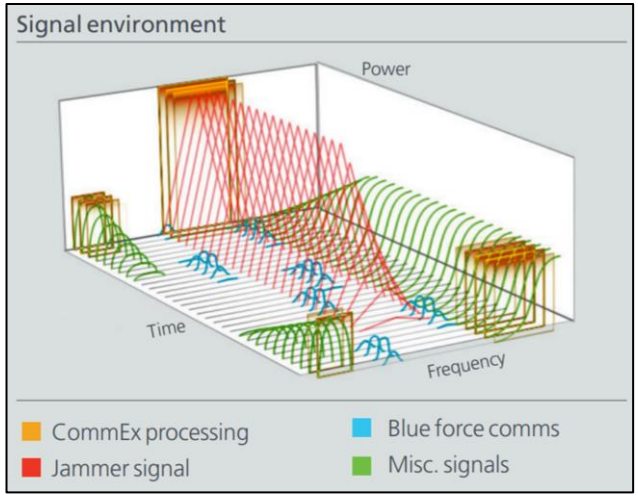


Maritime tankers and over-the-shore systems refuel bases and airfields



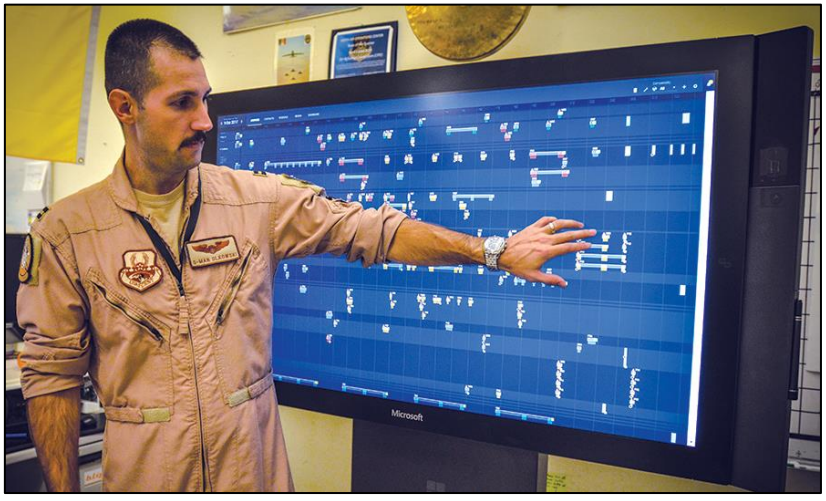
Changes to C3

- **Adopt new C2 tools for aerial refueling and broader operations**
  - New decision support and C2 tools
  - Orchestrate more sophisticated operations that impose complexity and tempo on adversaries
  - Mitigate effects of adversary action
- **Incorporate new communications systems to enhance interoperability and reduce vulnerability**
  - LPI/LPD advanced tactical data links



CommEx program provided anti-jam capabilities for Link 16

Whiteboard on which USCENTCOM tanker operations were planned

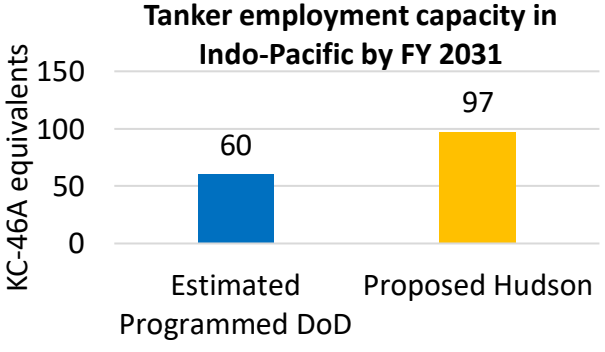


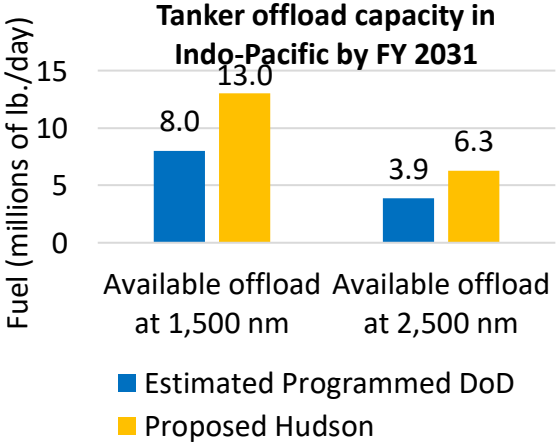
JIGSAW tanker operations planning tool

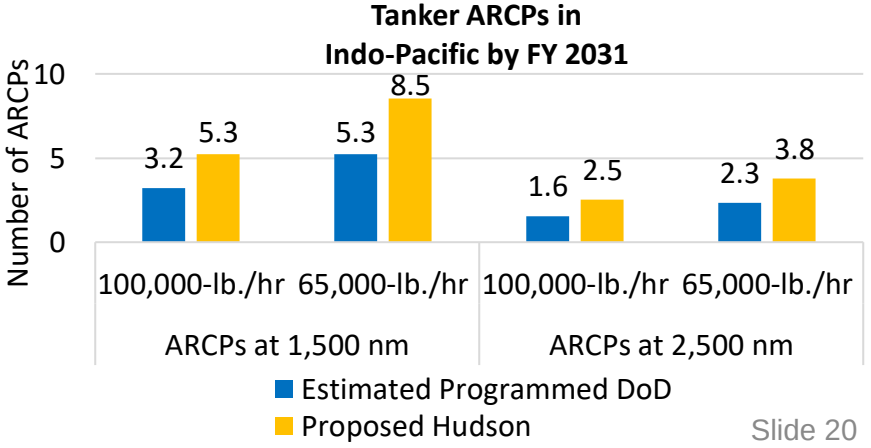
Proposed approach invests in critical posture and fuel distribution architecture

- **Invests additional funds in Indo-Pacific posture and distribution architecture**
  - Average $650 million more per year first decade; $400 million more per year thereafter
- **Proposed architecture outperforms DoD's programmed force by 63% within a decade**
  - More tanker capacity and ramp space for dispersal, more resilient fuel stores and distribution assets, more tanker offload capacity and ARCPs to enable distribution and tempo

Additional posture and distribution investments	Total Cost (FY 2022 millions of dollars)
8 x 1.6 million ft^2 tanker parking aprons	$767
4 x 9,000 ft runways with parallel taxiways	$388
4 x 220,000 bbl sets of aboveground storage tanks	$437
4 x 220,000 bbl sets of cut-and-cover storage tanks	$1,032
4 x 220,000 bbl sets of hardened underground storage tanks	$1,755
4 x Inland Petroleum Distribution Systems	$94
4 x Offshore Bulk Fuel Transfer Systems	$280
4 x Single Point Mooring Systems	$60
15 x Tanker Security Fleet slots funded for a decade	$1,500
Total	$6,333



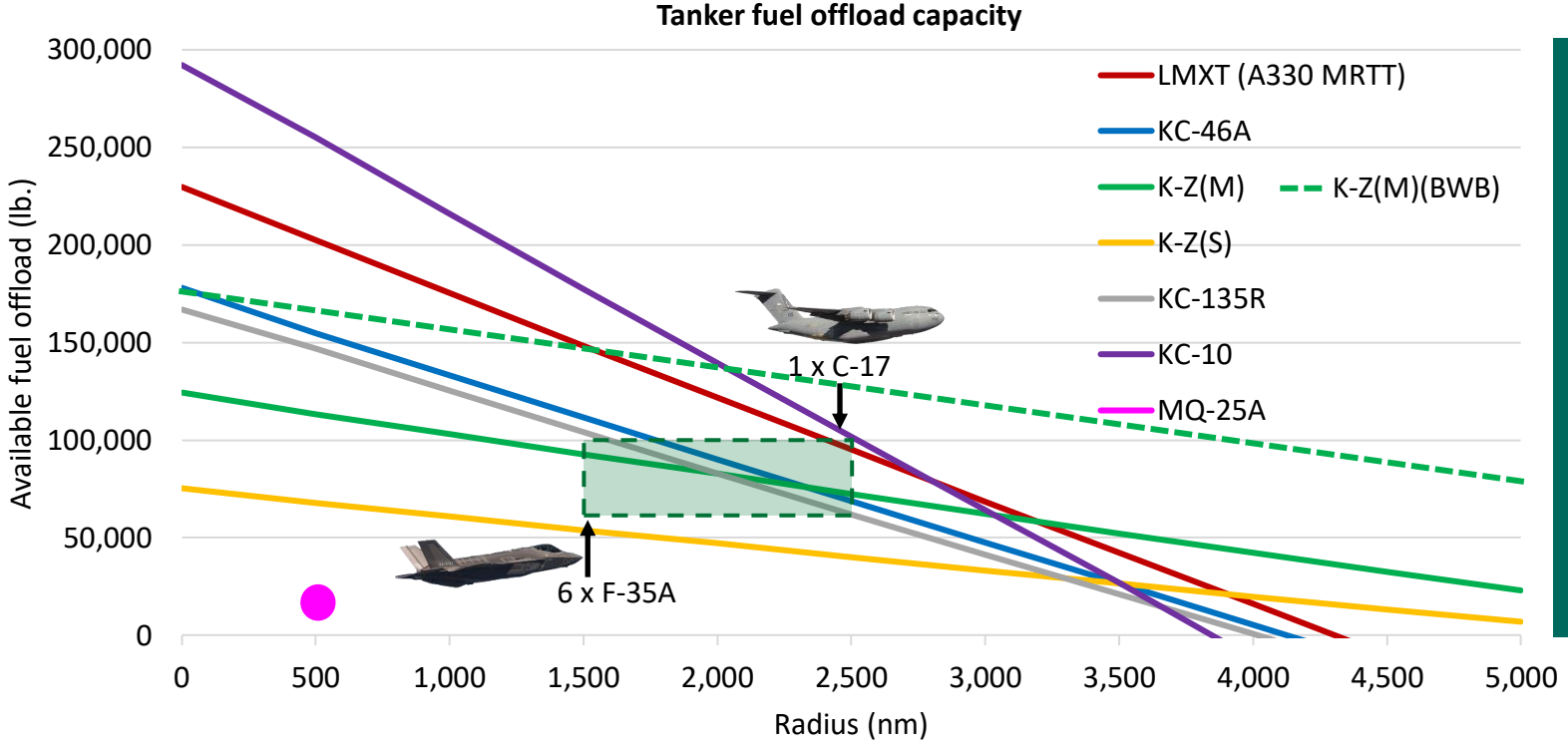




* Charts assume restrictive laydown and dispersal depicted on Slide 9.

Tanker capacity and size affect utility

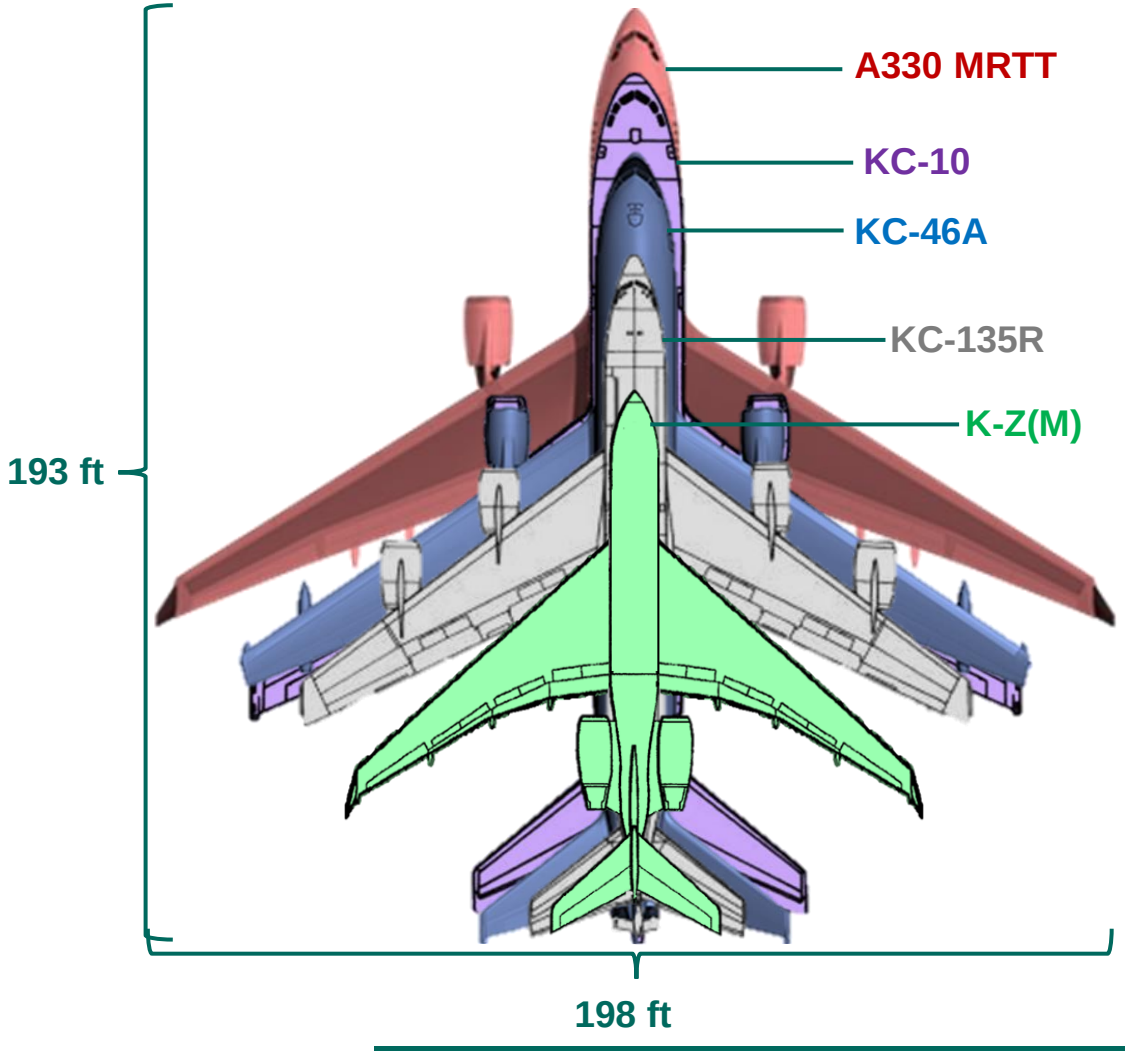
Estimates	LMXT (A330 MRTT)	KC-46A	K-Z(Medium) Wing-Body-Tail	K-Z(Medium) Blended Wing Body	K-Z(Small) Wing-Body-Tail	KC-135R	KC-10
Empty weight (lb)	265,055	204,000	95,000	126,900	70,000	122,500	250,000
Fuel capacity (lb)	268,445	211,000	140,000	225,621	85,000	202,000	356,000
Fuel fraction	0.50	0.51	0.60	0.64	0.55	0.62	0.58
Required C-17 Parking Spots	1.29	0.88	0.47	0.54	0.54	0.60	1.02

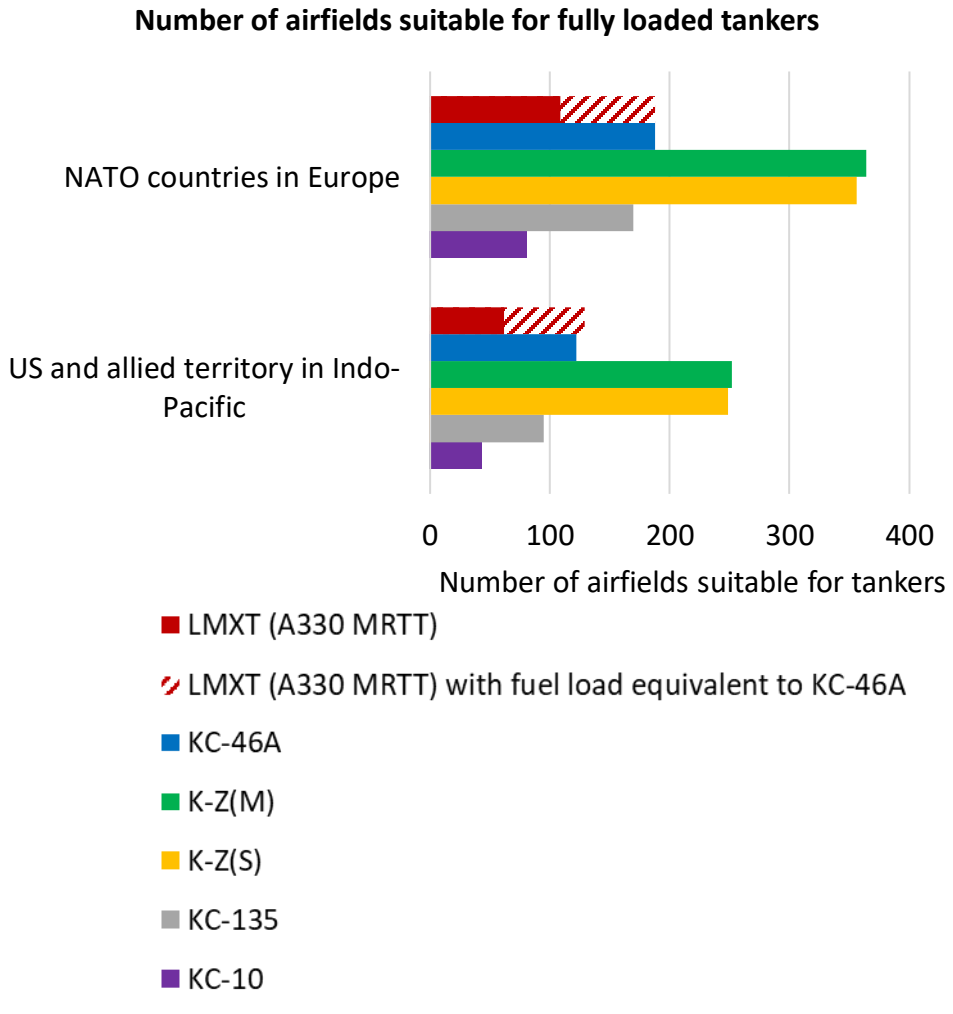


Tankers should be capable of refueling large aircraft or groups of smaller aircraft at range, and have enough fuel to account for operational exigencies and friction.

This and subsequent charts assume flights to and from an aerial refueling control point, one hour on station, and two hours of reserve.

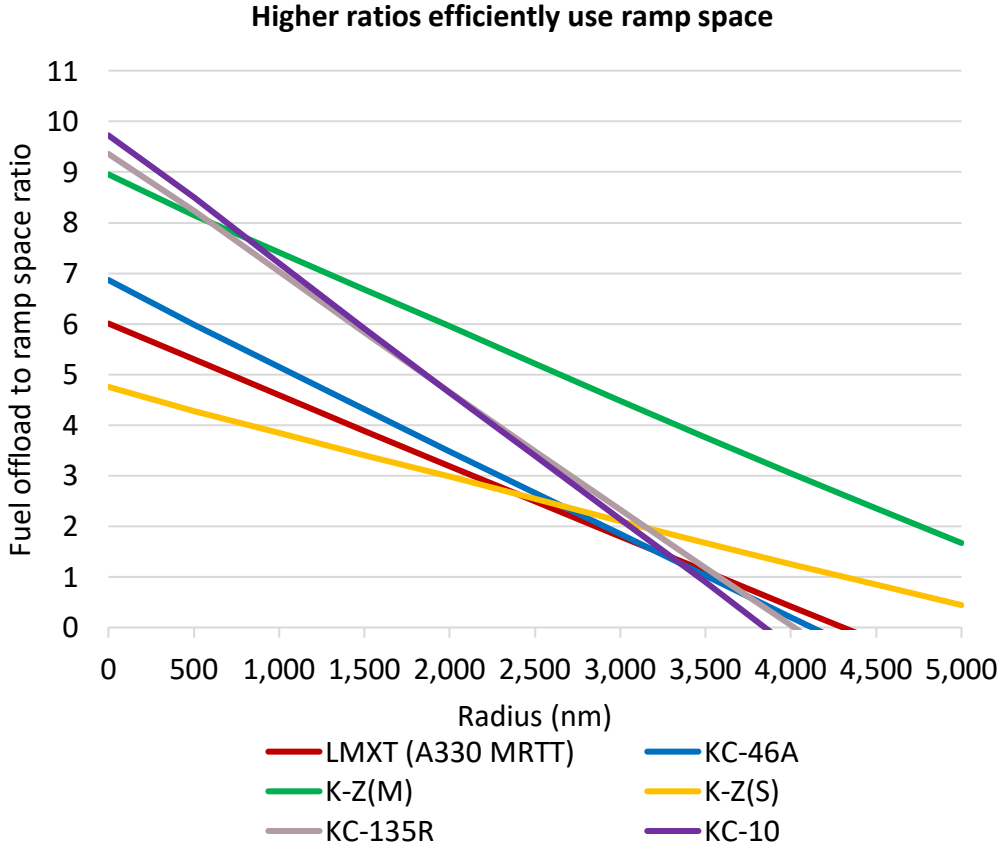
Smaller tankers can operate from more airfields

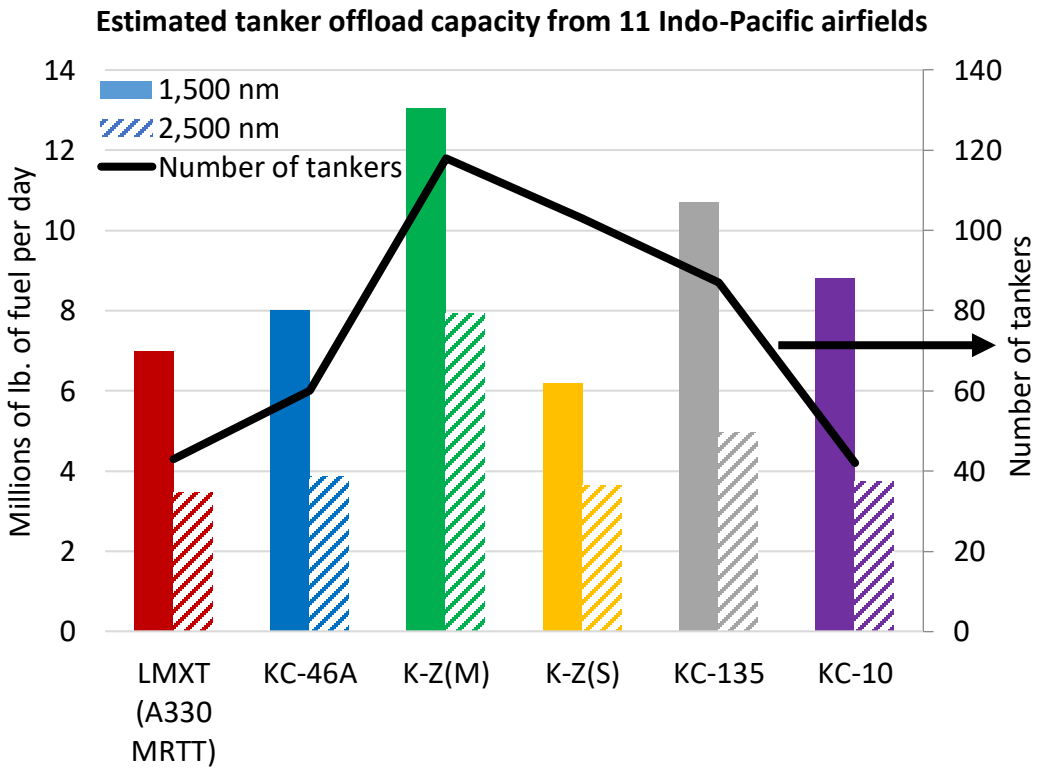




Access to more airfields can enhance operational resilience.

Tanker designs should maximize access to and efficient use of suitable airfields





Efficient use of ramp space enables more booms in the air and total fuel delivered.

Improved mission-tanker specialization can increase efficiency

Support from Eielson to 12 Ellsworth B-1Bs striking targets in Taiwan Strait

	LMXT (A330 MRTT)	KC-46A	K-Z(M)	K-Z(S)	KC-135	KC-10
Tankers required	23	32	30	55	36	22
Tanker ramp space required (millions of ft²)	4.30	4.05	2.04	4.30	3.14	3.23
Tanker procurement cost (billions)	$5.18	$6.12	$3.32	$3.59	N/A	N/A

Support from Pease to 6 Pope C-17s transporting forces to Ramstein

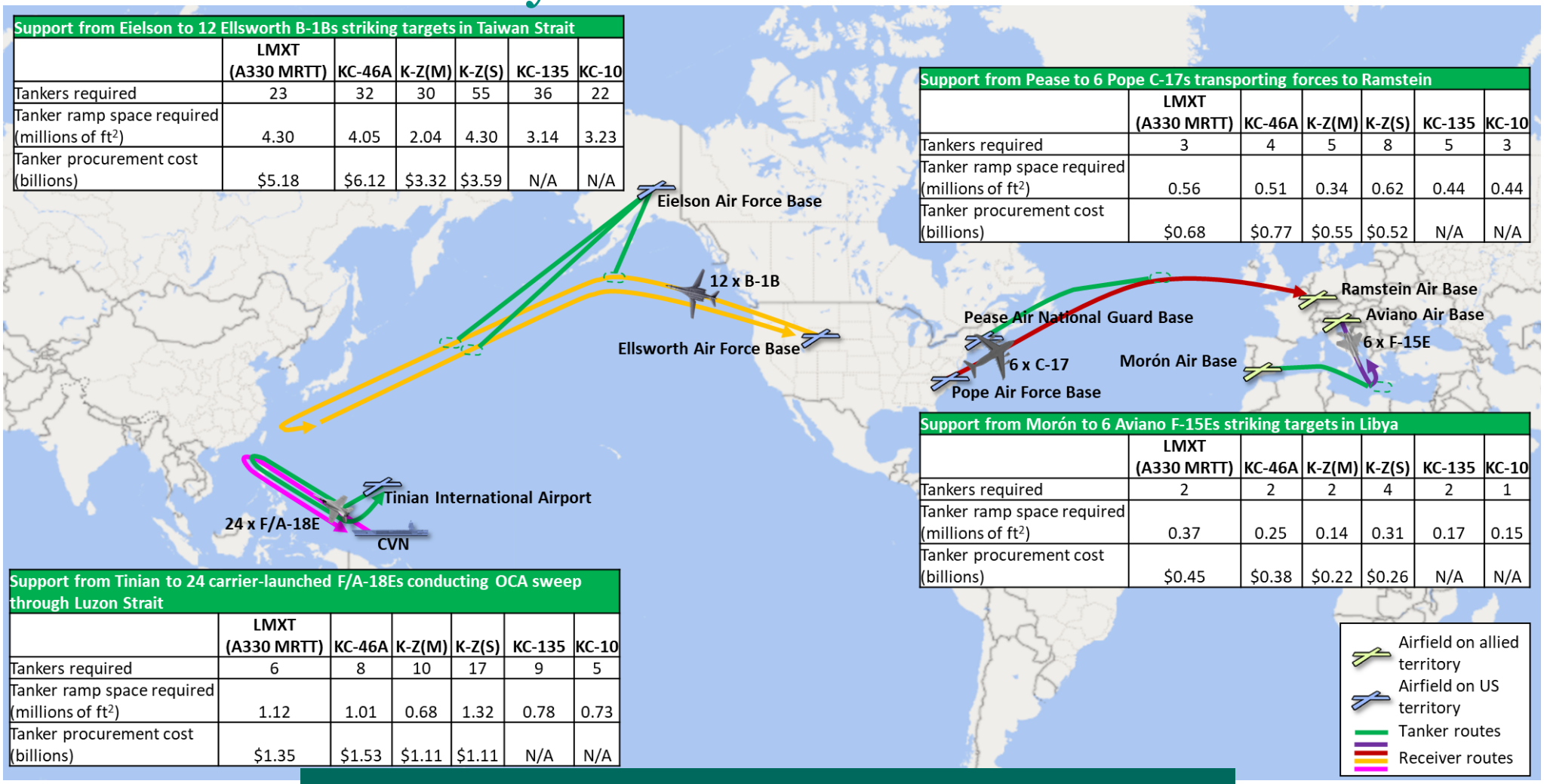
	LMXT (A330 MRTT)	KC-46A	K-Z(M)	K-Z(S)	KC-135	KC-10
Tankers required	3	4	5	8	5	3
Tanker ramp space required (millions of ft²)	0.56	0.51	0.34	0.62	0.44	0.44
Tanker procurement cost (billions)	$0.68	$0.77	$0.55	$0.52	N/A	N/A

Support from Morón to 6 Aviano F-15Es striking targets in Libya

	LMXT (A330 MRTT)	KC-46A	K-Z(M)	K-Z(S)	KC-135	KC-10
Tankers required	2	2	2	4	2	1
Tanker ramp space required (millions of ft²)	0.37	0.25	0.14	0.31	0.17	0.15
Tanker procurement cost (billions)	$0.45	$0.38	$0.22	$0.26	N/A	N/A

Support from Tinian to 24 carrier-launched F/A-18Es conducting OCA sweep through Luzon Strait

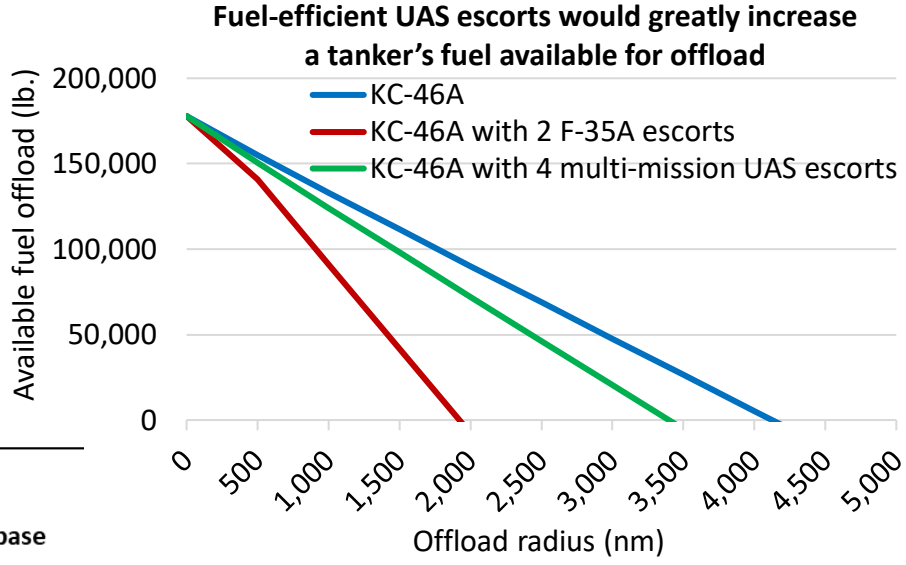
	LMXT (A330 MRTT)	KC-46A	K-Z(M)	K-Z(S)	KC-135	KC-10
Tankers required	6	8	10	17	9	5
Tanker ramp space required (millions of ft²)	1.12	1.01	0.68	1.32	0.78	0.73
Tanker procurement cost (billions)	$1.35	$1.53	$1.11	$1.11	N/A	N/A



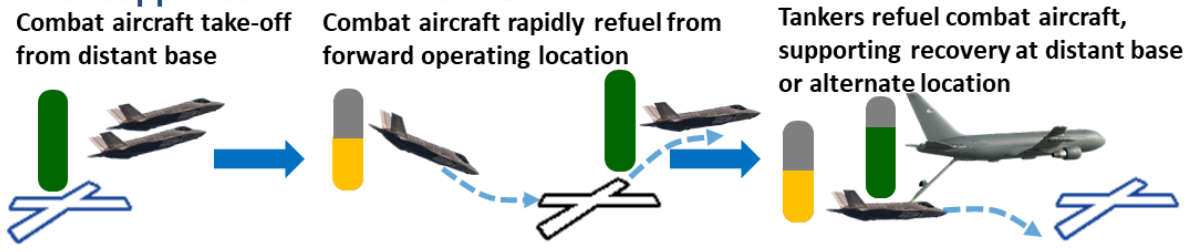
Larger tankers can focus on higher-offload missions.

Changes in non-tanker concepts and capabilities can improve performance and reduce O&S costs

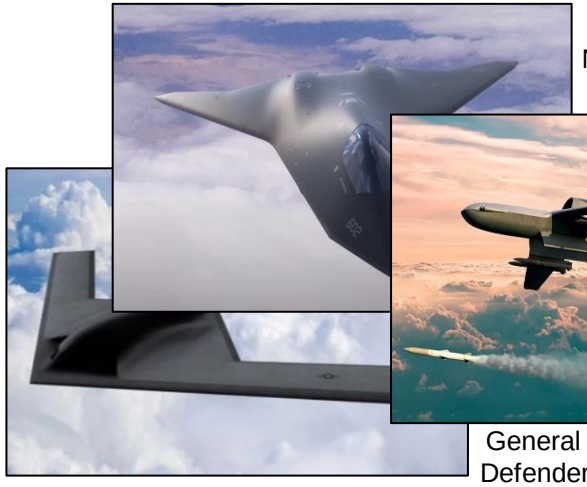
- **New concepts can reduce aerial refueling demands and contribute to a more lethal and dynamic force**
- **Capability changes can increase range and endurance and decrease O&S costs**
  - Adopt long range and endurance aircraft
  - Incorporate new engine technologies
  - Increase receiver onload rates



Tanker-supported shuttle missions



Changes to DCA CAPs enabled by new systems



Artist depiction of NGC B-21 bomber

Boeing concept for Next Generation Air Dominance fighter

General Atomics concept for Defender UAS protecting and refueling from tanker

Path forward for aerial refueling

Aerial Refueling Demands	Near-Term	Mid-Term	Long-Term
Enhanced surface infrastructure	More ramp space and runways, hardened fuel stores, and bulk fuel distribution assets	More ramp space and runways, hardened fuel stores, and bulk fuel distribution assets	More ramp space and runways, hardened fuel stores, and bulk fuel distribution assets
Recapitalization to replace aging airframes More tankers to offset wartime attrition (on the ground and in the air) New refueling concepts and capabilities for distributed, long-range, high-capacity offloads and operations near and in contested environments	Complete acquiring 179 KC-46A  KC-10 (possibly lease portion to commercial operators) 	Begin KC-46 or LMXT Bridge Tanker buy  Begin development and prototyping of K-Z KC-135 	Finish Bridge Tanker procurement  Field K-Z/KC-Z  KC-135 
	Field improved C3 capabilities Refine force extension and other concepts Develop defensive systems Define K-Z and mature requisite technologies	Iteratively improve C3 systems Field self-defense systems Field new transfer technologies Boom automation New boom/drogue designs Improved aircraft receive rates	Iteratively improve C3 systems Deepen mission specialization within tanker force Field highly automated refueling

Three representative plans to enhance the aerial refueling architecture

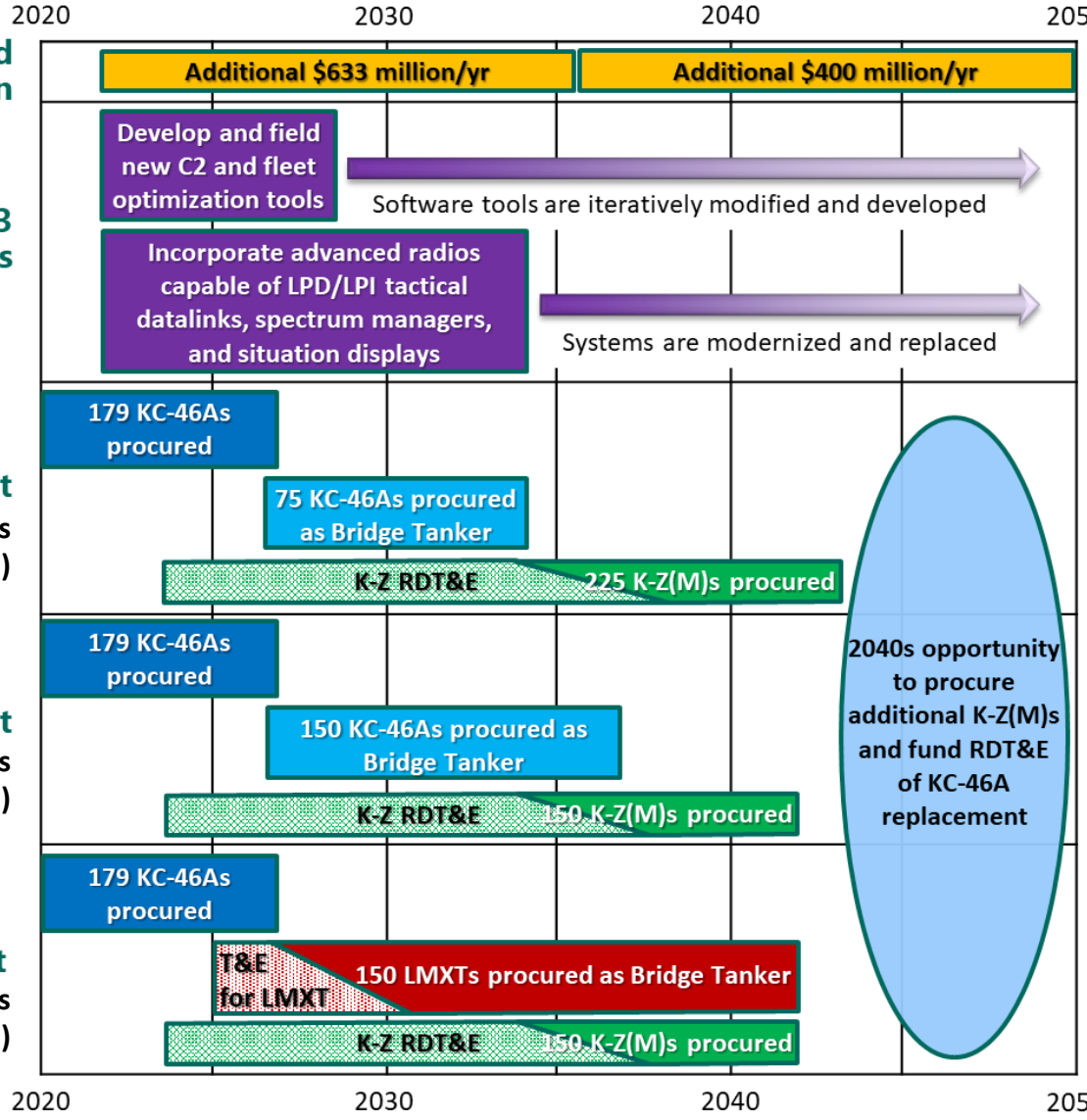
All plans prioritize posture and bulk fuel storage and distribution

All plans prioritize C3 improvements

Plan 1 aircraft
+75 KC-46A Bridge Tankers
+225 K-Z(M)

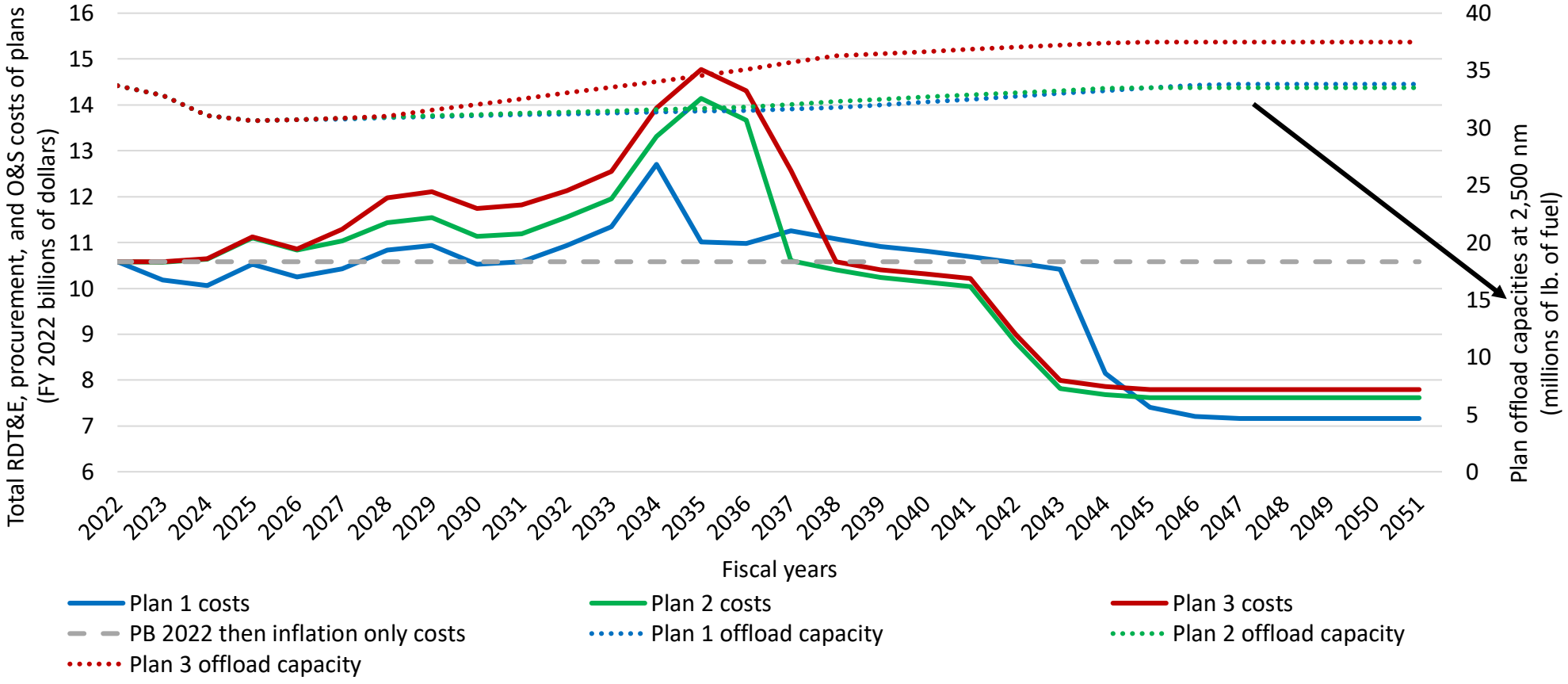
Plan 2 aircraft
+150 KC-46A Bridge Tankers
+150 K-Z(M)

Plan 3 aircraft
+150 LMXT Bridge Tankers
+150 K-Z(M)



All plans prioritize funding surface architecture, C3 improvements, and accelerating K-Z(M) RDT&E; differ in terms of mix of 479 tankers

Plan costs and offload capacities



Plan 1 (Truncated Bridge Tanker) largely stays within PB 2022 funding levels;
Plan 3 (150 LMXT Bridge Tankers) confers 11% more offload capacity at 2,500 nm than other plans.