The Collapse of American Air Power: High Technology Air Defense Weapons vs Planned US Force Structure

Dr Carlo Kopp,
SMAIAA, MIEEE, PEng
Head Capability Analysis
Air Power Australia

The Post Cold War Paradigm Shift

- Two decades have elapsed since the Warsaw Pact disintegrated.
- The 21st century "Multipolar" world: nascent "regional superpowers" in China, India, emerging regional powers like Iran, Russia has recovered from the post Soviet era economic collapse.
- Globalised market for high technology products.
- Global proliferation of advanced post-Soviet era Russian and Chinese hi-tech weapons technology.
- Commercially driven Russian and Chinese defence industries have large and growing intellectual capital and unconstrained market access globally.

Post Cold War Russian Weapons

- Modern high technology weapons
- Mostly digital processing rather than Cold War analogue hardwired technology
- Exploitation of globalised market for high technology components, materials, software and other basic technology
- Some weapons are evolved from late Cold War era designs
- Some weapons are entirely new post Cold War developments
- Many have no Western equivalents

Stated Russian Technological Strategy

- *Defeat US Air Power by defeating core technological capabilities*
- Defeat ISR by “lockout” using ultra-long range 200 NMI SAMs and AAMs.
- Defeat smart munitions like HARM and JDAM using countermeasures or shoot them down using SAMs and gun systems.
- Defeat SEAD/DEAD operations by high mobility design of air defence systems.
- Defeat/degrade stealth using low band radars and passive sensors.

Advanced Russian / Chinese SAMs

1. 2008: SA-21 (S-400) – 250km/400 km
2. 2008: PLA HQ-9/FD-2000 – 125 km
3. 2003: SA-X-23 (S-300VM/VMK) – 200 km
4. 2003: SA-20 (S-300PMU2) - 200 km
5. 1996: SA-20 (S-300PMU1) - 150 km
6. 1991: SA-10C (S-300PMU) – 75 km
7. 1991: SA-12 (S-300V) – 75 km

- *Missile kinematic range has increased 3 to 5 fold since the end of the Cold War.*
- *Commensurate increases in radar power output improves detection of LO targets.*

Advanced Russian / Chinese SAMs

- “Patriot class” weapons but with many refinements and improvements.
- Fully mobile ~5 minute “shoot and scoot”.
- Jam resistant frequency hopping phased array radars; passive tracking of jammers.
- Digital processing / radio networked systems; COTS technology.
- Integrated with low band radars.
- Integrated with passive emitter locating systems.
- Hypersonic missile designs.

SAM Trajectory Shaping for Long Range

- Conventional SAM trajectories based on modified proportional or pursuit algorithms.
- Long range trajectories based on ballistic flight path with apogees as high as 40 km.
- The SAM will dive down at its target, accelerating to the endgame to maximise G performance.
- TVC SAM has 20G aerodynamic capability.
- Directional shaped charge warhead designs.
- Ballistic trajectory shaping introduced in SA-20 48N6E2 missile design.

Advanced Low Band Search Radars

- Active Electronically Steered Arrays (AESA).
- Designed for high angle/range accuracy to support long range SAM shots.
- Designed to operate in bands below LO/VLO shaping optimisations of US fighters.
- Highly mobile “shoot and scoot” designs.
- VNIIRT 67N6 Gamma DE – L-band AESA.
- NNIIRT 1L119 Nebo SVU – VHF-band AESA.
- Accuracy sufficient for SAM midcourse guidance updates.

Networked Emitter Locating Systems

- Evolved from Cold War era Soft Ball (KRTP-81) and Trash Can (KRTP-86/91).
- Precision geolocation of airborne emitting targets using Time Difference Of Arrival and /or interferometry techniques.
- Effective against radar and network terminals.
- Russian 85V6 Vega/Orion, 1L222 Avtobaza.
- Ukrainian Topaz Kolchuga.
- Chinese CETC YLC-20 system.
- Growth capability vs Low Probability of Intercept radars and networks.

Advanced SAM CONOPS

- Operational concept is "*wait silently in hidden ambush, move frequently*".
- All components "shoot and scoot", missile launchers and engagement radars on 5 minute cycle.
- All components networked with radio links.
- Exploit passive sensors, low band radars, AWACS and other remote search / track systems to cue and/or guide SAM shots.
- CONOPS evolved from OAF SA-6 operations.
- Hide and evade SEAD/DEAD aircraft.

SAM Battery / Radar Self Protection

- *New defensive CONOPS combining mobility, countermeasures, and active defensive fire against inbound smart munitions.*
- Countermeasures may include flares, chaff, synchronised emitting decoys, laser decoys, and Missile Approach Warning Systems.
- Battery components defended by high mobility radar / electro-optically aimed 30 mm gun systems or short range guided missiles.
- CONOPS similar to warship defensive systems.
- Significant lethality against HARM, JASSM.

Legacy SAM Mobility/Radar Upgrades

- Rehosting of Cold War era semi-mobile and static SAMs on to tracked or wheeled vehicles to provide mobile TEL capability.
- Replacement of legacy radar processing with digital hardware/software; frequency hopping radar waveforms; decoy integration.
- SA-2/HQ-2B/J PLA upgrades.
- SA-3 upgrades ByeloRussia, Russia, Cuba.
- SA-6 rehosting to new wheeled vehicles.
- SA-8 rehosting to new wheeled vehicles.
- SA-11/17 rehosting to new wheeled vehicles.

Legacy SAM System Hybridisation

- Replace legacy Cold War era engagement radar with digital phased array to improve radar range, jam resistance and reliability.
- SA-5 Gammon: Square Pair engagement radar controlled by 30N6E2 (SA-20) or 92N6E (SA-21) phased array.
- SA-2/HQ-2 Guideline: satellite imagery showing replacement of Fan Song with new H-200 (KS-1A) phased array.
- Legacy EW capabilities obsoleted by new radar technology and waveform.

SAM System Technology Trends

- More radar peak power output:
  ESA->AESA technology
- More digital processing.
- More jam resistance.
- More mobility.
- More countermeasures and decoys.
- More networking and integration.
- Multiple sensor band acquire/track.
- Track data fusion (cf USN CEC).
- Further hybridisation of components.

Operational Impact of Advanced Air Defence Systems: Obsolescence of Legacy / F-35 Penetration CONOPS

Established US Penetration CONOPS

- Vietnam era CONOPS evolved through Desert Storm, OAF and OIF.
- Threat radars jammed by EA-6B, to be replaced by EA-18G; ALQ-99 jammer.
- AGM-88 HARM/AARGM missiles fired to force shutdowns or kill radars.
- Stealth fighters bypass SAM defences to hit high value targets.
- SAM systems and radars actively hunted down to open “corridors” through SAM belts enabling non-VLO fighter penetration.

Defeat of Established US Penetration CONOPS

- Jammer effect against newer threat radars degraded by improved radar jam resistance.
- Long range missile shots to deny jammer use; passive tracking of jammers.
- AGM-88 HARM/AARGM, GBU-31/32 JDAM, GBU-39 SDB defeat by countermeasures or killed by defences.
- AGM-158 JASSM defeat by mobility.
- Conventional defence suppression aircraft are vulnerable to long range SAM shots.

Defeat of Legacy US Fighters

- Traditional defence suppression CONOPS is no longer effective.
- Large radar signature of legacy fighter types such as the F-16C, F-15C/E and F/A-18A-F reduces effectiveness of defensive countermeasures and towed decoys.
- Networking of radars and passive sensors, radar passive track capabilities overcome jamming of X-band engagement radars.
- *All legacy US fighters including F/A-18E/F/G would suffer unsustainable loss rates in combat.*

Defeat of F-35 Joint Strike Fighter

- Stealth design of F-35 optimised against legacy short and medium range SAM radars.
- Poor stealth performance in rear hemisphere as penetration of long range SAM defences not part of JSF basic design definition.
- F-35 susceptible to “pop-up” SAM shots, and susceptible to tail aspect SAM shots during egress manoeuvres.
- F-35 is too slow to escape tail aspect SAM shots by retreating out of tracking range.
- *F-35 would suffer unsustainable loss rates in combat.*

Defeat of F-35 Joint Strike Fighter

- *F-35 electronic warfare capabilities poorly defined against advanced SAM threats.*
- AESA jamming capabilities limited to forward sector where least required;
- AESA jamming can be exploited to passively guide SAM shots against F-35 AESA;
- AESA jamming is ineffective against low band threat radars;
- Expendable decoys have limited effect against smart digital missile guidance;
- Wideband aft jammers difficult to fit.

F-22 Raptor is the Only Viable US Asset

- High mobility and survivability of advanced SAM systems precludes rapid attrition and opening of “corridors” through SAM belts.
- *Intended “silver bullet” CONOPS of F-22 killing off SAMs to “enable” F-35 JSF is no longer viable as advanced SAMs are much more survivable.*
- F-22 stealth and supercruise allows it to bypass advanced SAM defences and hit targets directly.
- The F-22 is the only US fighter capable of penetrating such defences. F-35 design and CONOPS is no longer viable due to SAM evolution.
- The US will require enough F-22s to cover strike, air combat and ISR roles alone.

How many F-22s are Needed?

- Established number of 433 aircraft based on block replacement of F-15A/C fleet.
- This assumed “silver bullet” use as enabler for less capable F-35 fleet.
- OAF scale contingency needs: DCA/OCA, Strike/ISR missions total ~300 F-22As.
- Desert Storm scale contingency needs: Strike/ISR missions total ~600 F-22As.
- Taiwan / PRC scale contingency needs: 600 – 1,000 subject to operational assumptions and intended optempo.


Advanced Russian and Chinese
Air Defence Systems

S-400 Triumf / SA-21– 130-200 NMI

92N2E Grave Stone Engagement

4/16 Round 5P85TE1 TEL

96L6 Cheese Board – Acquisition

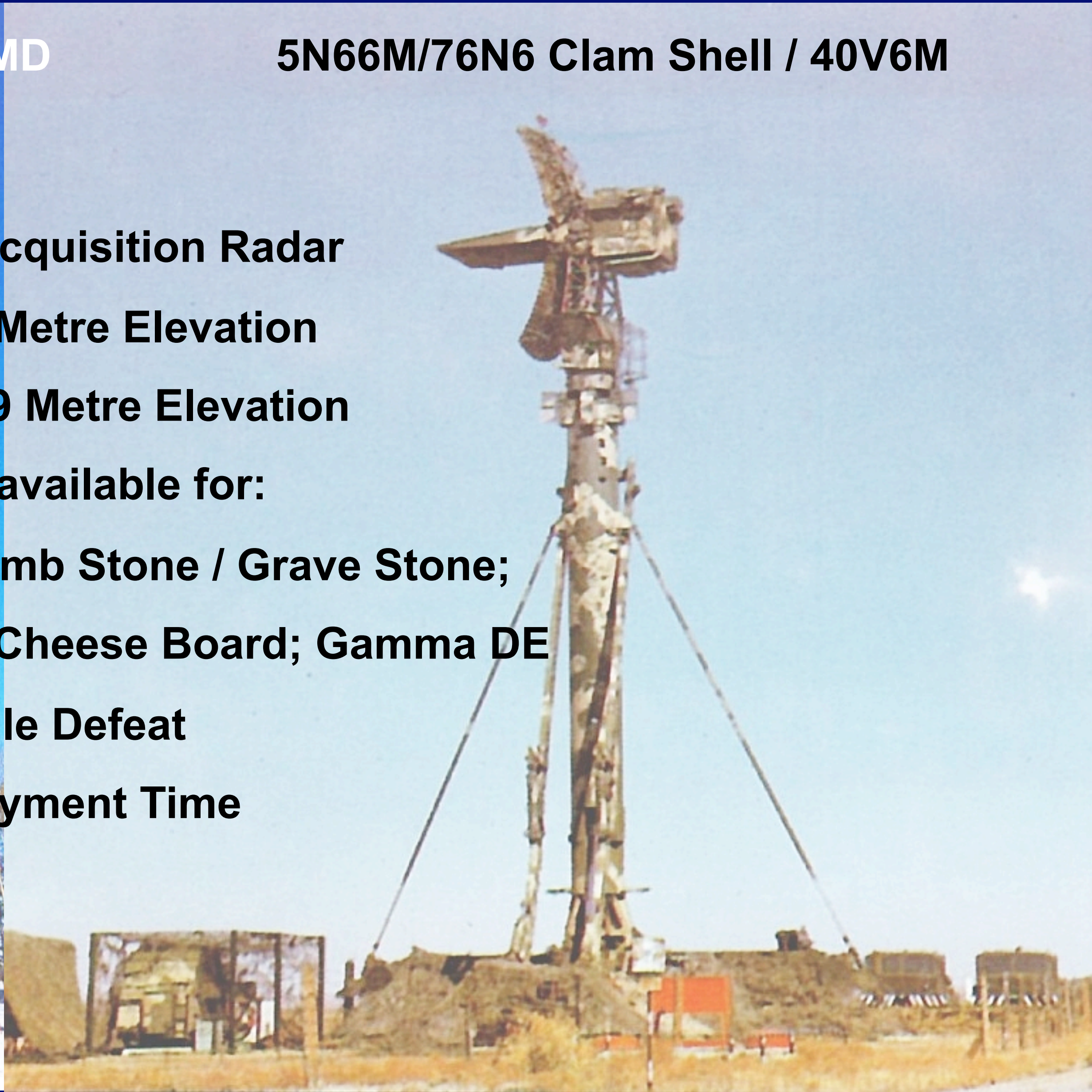
Missiles 48N6E3, 40N6, 9M96E/E2

Equivalent Patriot PAC-3 / ERINT

S-300PMU1/2 / SA-20 Gargoyle – 80-110 NMI

S-300PMU1/2 / SA-20A/B Gargoyle Radars

5N66M/76N6 Clam Shell / 40V6MD



5N66M/76N6 Clam Shell / 40V6M

Low Level Acquisition Radar

40V6M – 24 Metre Elevation

40V6MD – 39 Metre Elevation

Both masts available for:

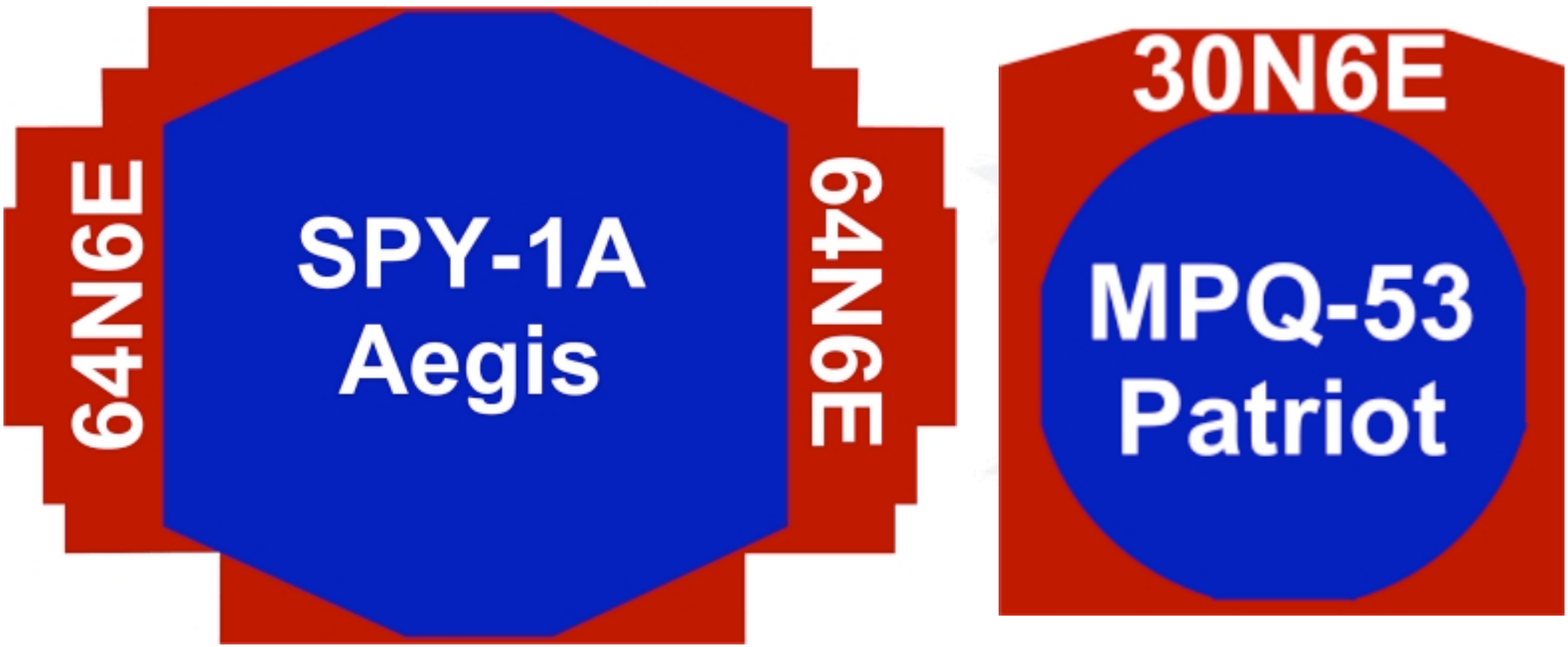
Flap Lid / Tomb Stone / Grave Stone;

Tin Shield ; Cheese Board; Gamma DE

Cruise Missile Defeat

2-4 hr Deployment Time

S-300PMU2 vs Aegis/Patriot - Comparisons



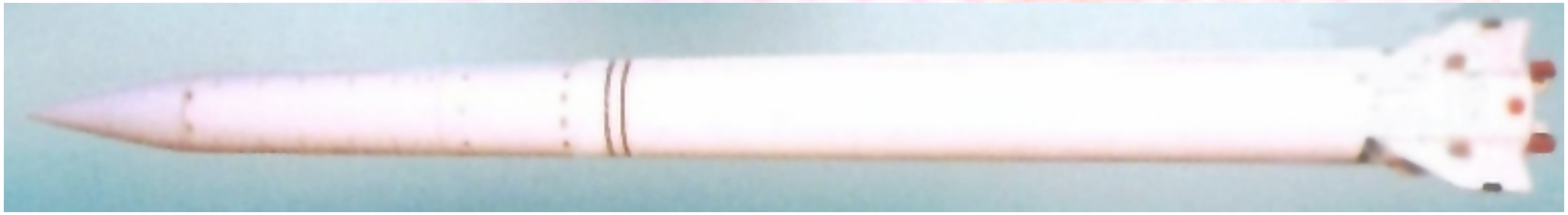
CPMIEC FD-2000 / FT-2000 / HQ-9

HT-233 Engagement Radar

YLC-2V Acquisition Radar

SA-10/20 technology

FT-2000 anti-radiation round 2-18 GHz



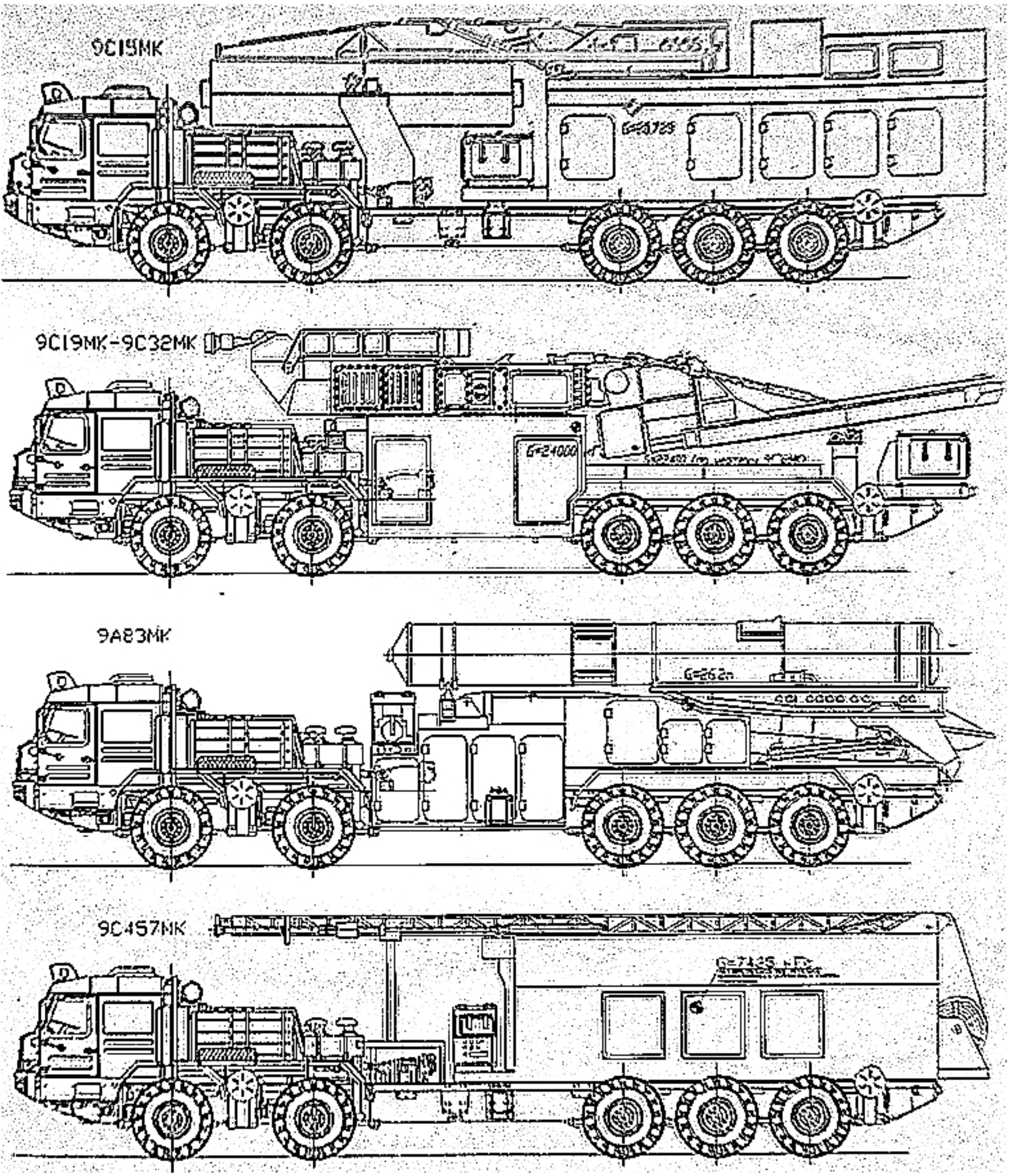
S-300VM / SA-X-23 ~110 NMI

- 9S32M Engagement Radar
- 9S15MT2 Acquisition Radar
- 9S19M ABM Radar
- High Performance SAM/ABM
- Growth Antenna in 9S32M

Image © Miroslav Gyűrösi

Image © Miroslav Gyűrösi

S-300VMK / SA-X-23 ~110 NMI



Wheeled High Mobility Variant

9S32M Engagement Radar

9S15MT2 Acquisition Radar

9S19M ABM Radar

High Performance SAM/ABM

Growth Antenna in 9S32M

S-300V / SA-12 Giant/Gladiator ~40 NMI

9S32 Engagement Radar

9S15 Acquisition Radar

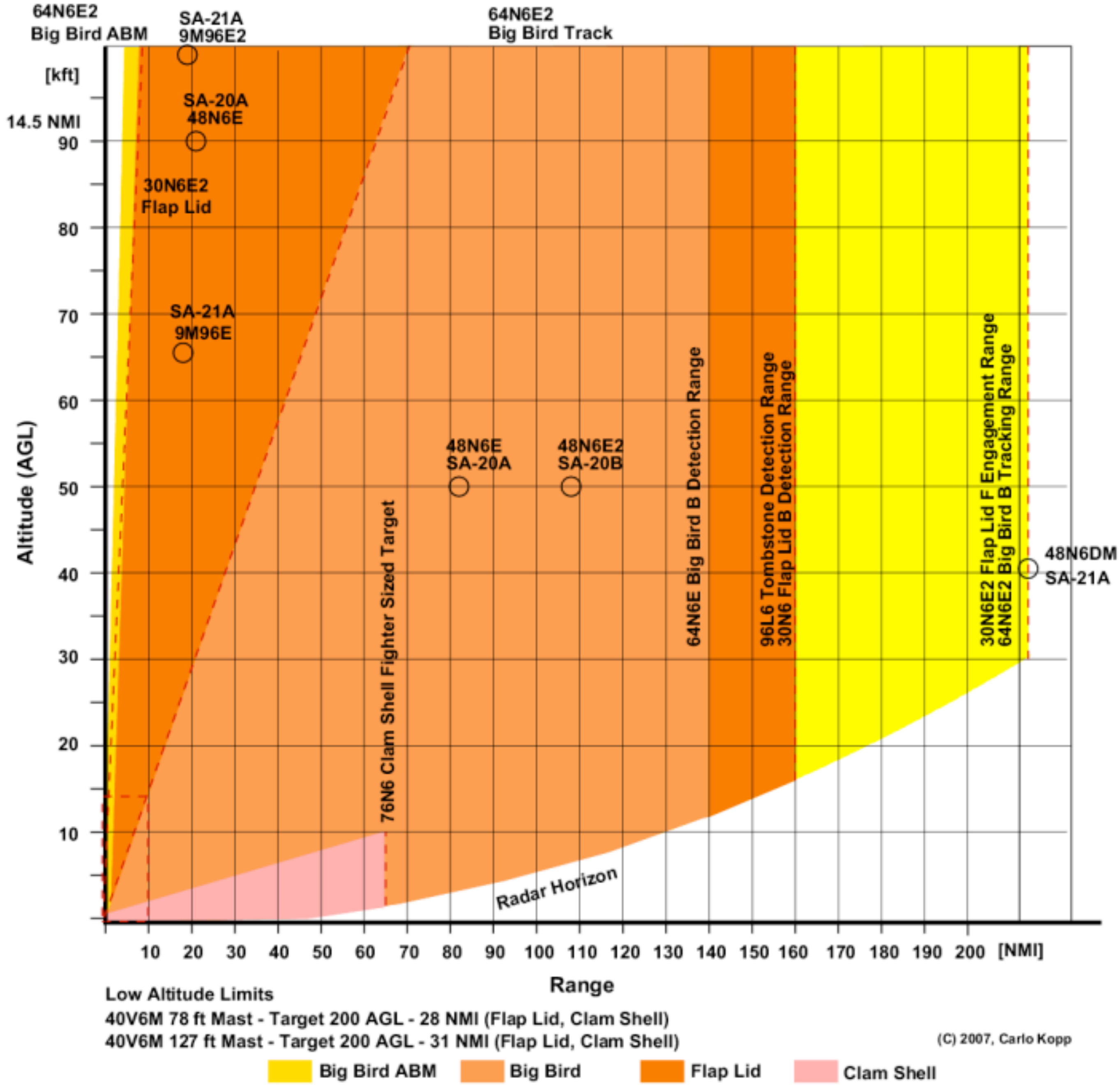
9S19 ABM Radar

High Performance SAM/ABM

Image © Miroslav Gyűrösi

Image © Miroslav Gyűrösi

S-300PMU-2 Favorit (SA-20 Gargoyle) Engagement Envelope
S-400 Triumf (SA-21 Growler) Engagement Envelope



Low Altitude Limits
40V6M 78 ft Mast - Target 200 AGL - 28 NMI (Flap Lid, Clam Shell)
40V6M 127 ft Mast - Target 200 AGL - 31 NMI (Flap Lid, Clam Shell)

Tor M2E / SA-15D Gauntlet D

Primary Role:

Interception of HARM and JDAM PGMs in Flight

Interception of Cruise Missiles

Phased Array Engagement Radar

Tor M1 / SA-15C Gauntlet C

Pantsir S2 / SA-22B Greyhound B

2S6M1 Tunguska M / SA-19C Grison C

LR66 / Type 347G / LD-2000 SPAAG

Primary Role: Interception of HARM and JDAM in Flight

Interception of Cruise Missiles

Based on naval CIWS with 30 mm Gatling

Almaz-Antey Laser Directed Energy Weapon

Beam Director on MAZ-7930

Development Project

Modelled on US THEL, but mobile

Demonstrator with CO_2 GDL

Passive Emitter Locating Systems

Topaz Kolchuga M ELS

85V6 Vega/Orion ELS

CETC YLC-20 ELS

Passive Detection;

2/3D Triangulation

Midcourse Missile Guidance:

S-400 / SA-21 Integration

1L119 Nebo SVU 3D VHF AESA Radar

2 Metre Band Operation

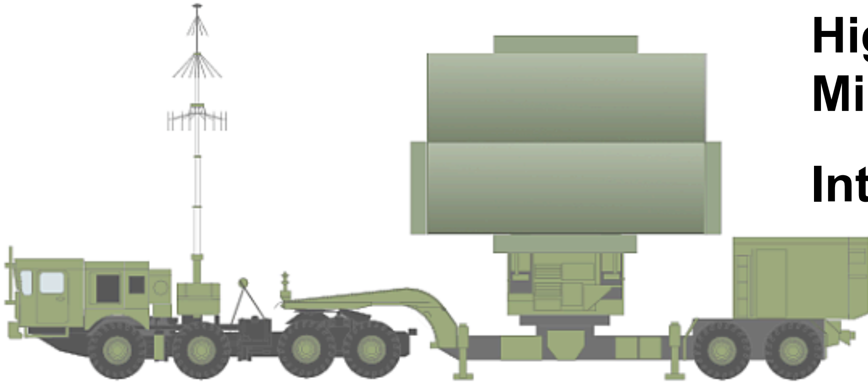
Defeats VLO Shaping in JSF

High Accuracy – Intended Midcourse Guidance of SAMs

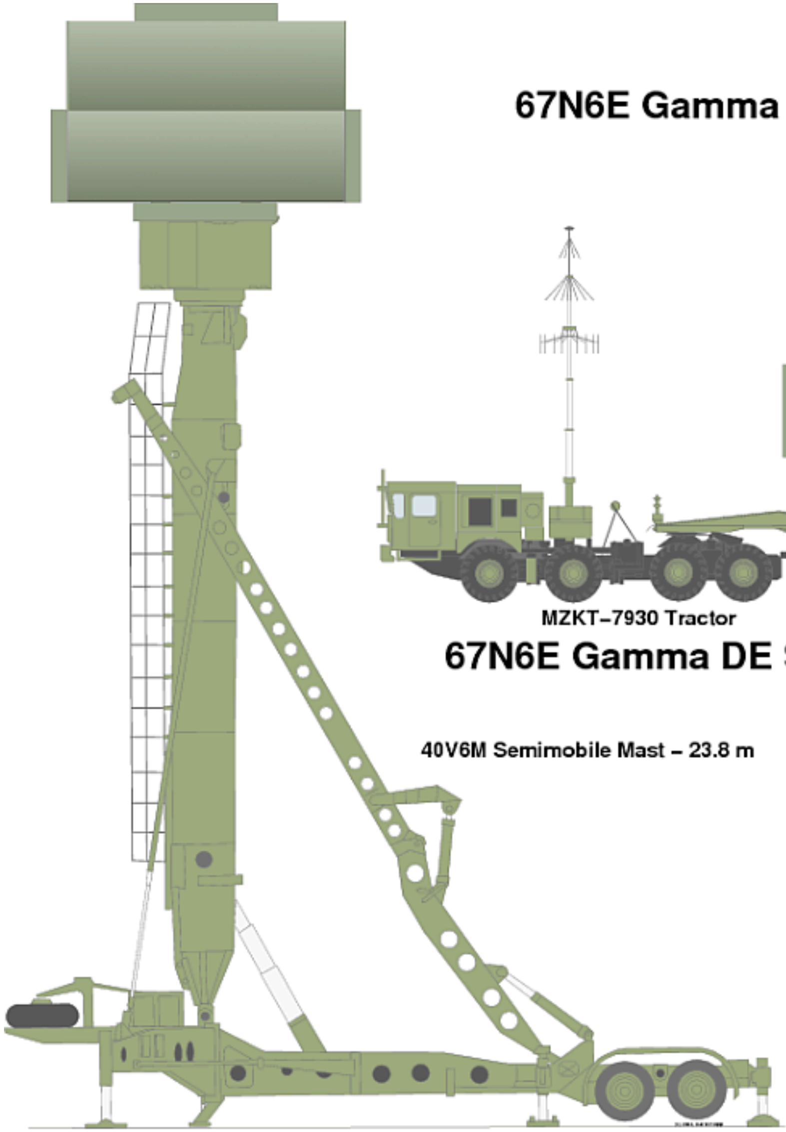
67N6E GAMMA-DE 3D L-Band AESA Radar

- L-Band Operation
- Defeats VLO Shaping in JSF
- High Accuracy – Intended Midcourse Guidance of SAMs
- Integrated Countermeasures

67N6E Gamma DE L–Band AESA



67N6E Gamma DE Self Propelled Variant



VNIIRT 67N6E Gamma DE / 40V6M (Deployed)

KBR Vostok E High Mobility 2D VHF Radar

Mobile ~8 min Stow/Deployment

Long Range 2D VHF AESA Radar

Digital MTI Processing

Intended Use vs VLO Targets

Advanced Antenna Design

NNIIRT Nebo UE Tall Rack 3D VHF Radar

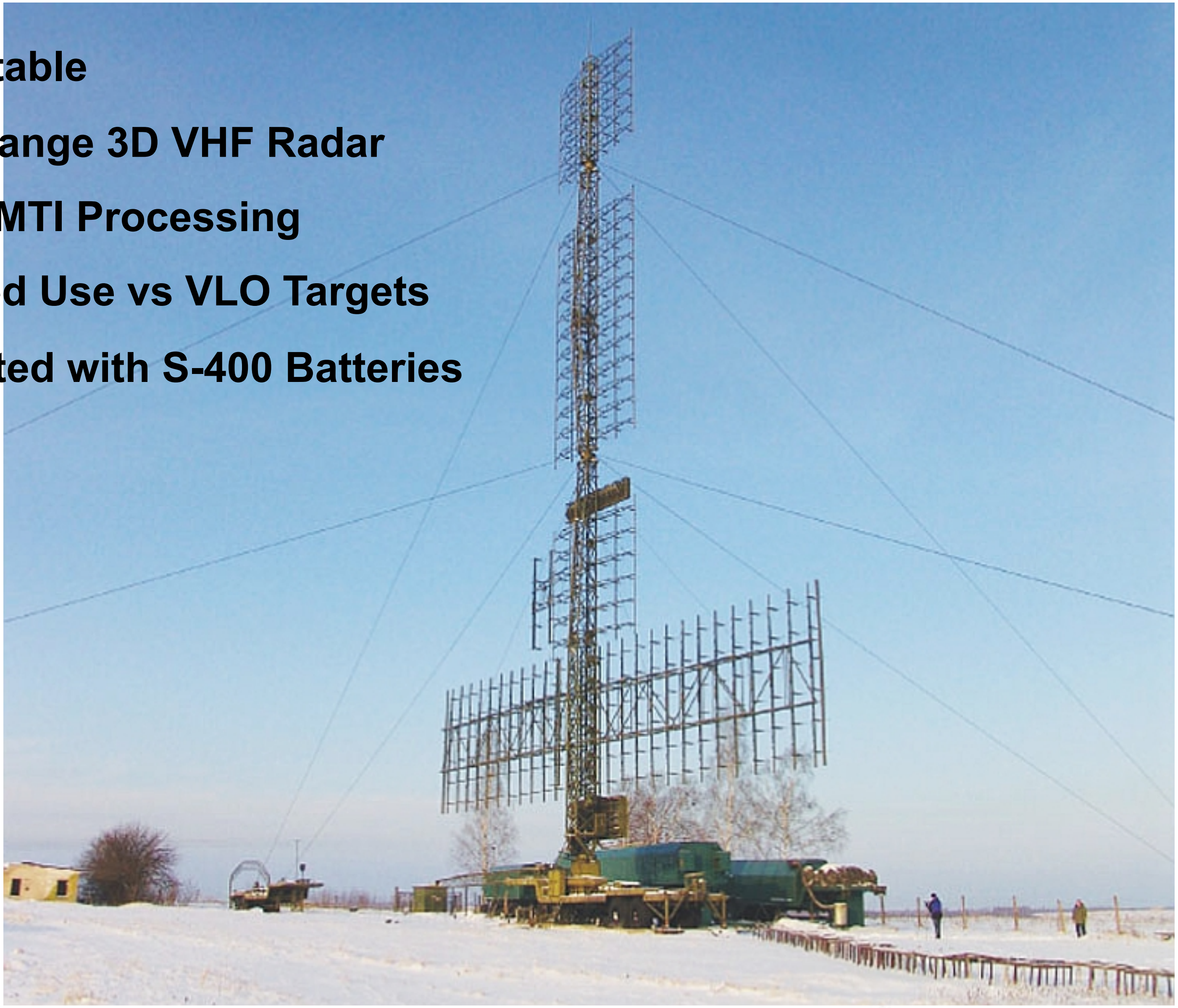
Relocatable

Long Range 3D VHF Radar

Digital MTI Processing

Intended Use vs VLO Targets

Integrated with S-400 Batteries



NNIIRT Nebo SV 2D VHF Radar

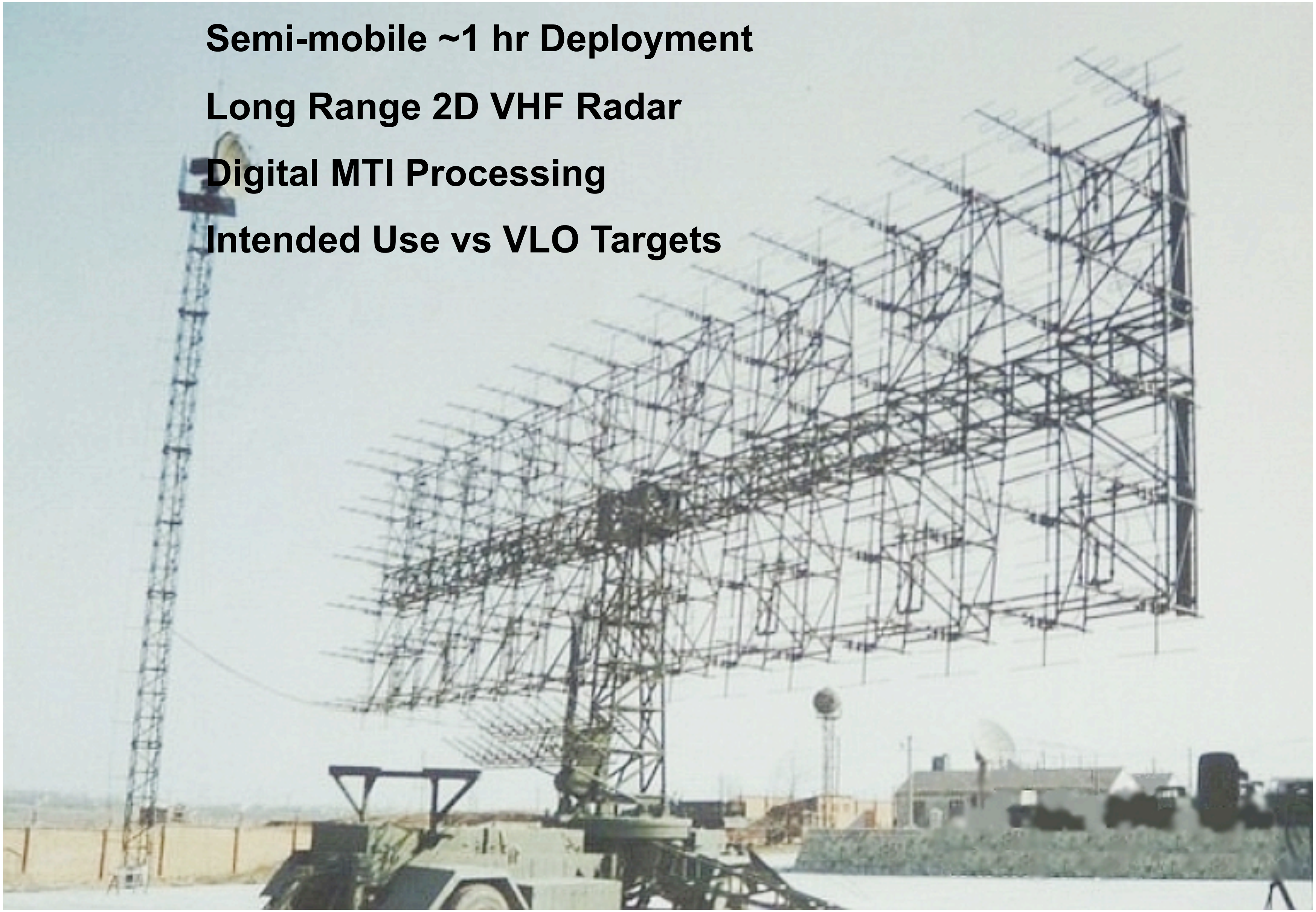
Mobile ~1 hr Deployment

Long Range 2D VHF Radar

Digital MTI Processing

Intended Use vs VLO Targets

CETC YJ-27 Long Range 2D VHF Radar



SA-2 Guideline Mobility Upgrades

Fully Mobile Deployment

PLA developed HQ-2 TEL

Cuba rehosted Soviet SA-2 on T-55 chassis

SA-3 Goa Mobility Upgrades

Fully Mobile Deployment

ByeloRussian Wheeled TEL

Cuban, Polish T-55 chassis TEL

SA-5 Gammon/SA-20 Hybridisation

Square Pair controlled by modern Tomb Stone / Grave Stone phased array

Improve jam resistance and lethality of SA-5 Gammon

HQ-2/SA-2 Guideline Hybridisation

H-200 phased array engagement radar for KS-1A SAM

Candidate Fan Song replacement in hybrid SA-2 batteries.