Feasibility of Third World Advanced Ballistic & Cruise Missile Threat

Volume 1: Long Range Ballistic Missile Threat

Presented to
67th MORS Symposium
Working Group 4: Air and Missile Defense, TMD Threat

June 24, 1999

Robert E. Woodside
robert.e.woodside@boeing.com

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
24-06-1999

2. REPORT TYPE
Technical Study

3. DATES COVERED *(From - To)*
1998-1999

4. TITLE AND SUBTITLE

Feasibility of Third World Advanced Ballistic and Cruise Missile Threat: Volume 1: Long Range Ballistic Missile Threat

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)

Robert Woodside, John McIver, Daniel Gadler, James Beyar, James Howe, Milton Gussow, Thomas K. Jones, H. William Beuttel, Theodore Kramer, Steven Woodall

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Defense Industrial
Association (NDIA)
2111 Wilson Blvd., Suite 400
Arlington, VA 22201

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Sea Systems Command
2531 Jefferson Davis Highway
NC#2
Arlington, VA 22242

10. SPONSOR/MONITOR'S ACRONYM(S)
OPNAV PEO (TSC)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
N/A

12. DISTRIBUTION / AVAILABILITY STATEMENT
The NDIA Study "Long range Ballistic Missile Threat" has been reviewed and is approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Abbreviated study materials presented at 67th Military Operations Research Society Symposium at US Military Academy 24 June 1999.

14. ABSTRACT
"Feasibility of Third World Long Range Ballistic Missile Threat" presents the results of a United States aerospace industry study which assesses the likelihood of a Third World country developing a long range (3,000-10,000 km) ballistic missile (LRBM) system and the estimated time to field it. A 10,000-km range ballistic missile launched from North Korea, for example, can reach the western and central regions of the United States. Likewise, a 5,000-km range missile launched from Iran could reach cities throughout Western Europe. The study contains four technical sections: historical developments and technology migration, trends in Third World ballistic missile weaponry, threat development on a compressed schedule, and candidate LRBM configurations. The report is unclassified because it drew exclusively upon unclassified sources of information. The study traces the history of the LRBM threat from Germany's V-2 rockets of World War II to the present. It shows how Third World countries could quickly field and launch LRBMs with technical assistance and components imported from developed nations. The study examines five different options by which a Third World country could achieve a long range ballistic missile capability: Buy a long range ballistic missile; Buy and convert an available space launch vehicle; Cluster or stack existing tactical missiles as boosters; Design and build a booster and use existing tactical missile for upper stage; or Design and build an entire missile. The flight stability and performance characteristics of feasible Third World missile configurations are based on industry experience in the design of missile systems and verified by the use of standard engineering analysis tools and missile flight simulations. The report contains the estimated time required for a Third World nation to develop each option as measured from program start to first launch. The study concludes that the time between detectable evidence of a country's missile development program until the missile is fielded may be less than the time needed to build defenses against it.

15. SUBJECT TERMS
Ballistic missiles, history, technologies, guidance, warheads, propulsion, employment, threats, advanced weapons, proliferation, performance simulation, design synthesis

16. SECURITY CLASSIFICATION OF: UNCLASSIFIED			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED	Unlimited	48	Robert E. Woodside
					19b. TELEPHONE NUMBER *(include area code)* (253)773-4164

NDIA
NATIONAL DEFENSE INDUSTRIAL ASSOCIATION

Feasibility of Third World Advanced Ballistic & Cruise Missile Threat

Volume 1: Long Range Ballistic Missile Threat

Prepared By
Systems Assessment Group
NDIA Strike, Land Attack and Air Defense Committee

Released
November 1998

Study Approach

- Review lessons learned from historical missile development programs
  - WW II Germany, North Korea, Iraq
  - Development time and motivation
  - Strategic objectives for LRBMs with WMD warheads

- Assess potential range growth of evolving family of Third World TBM threats to include LRBM capability (3,000km - 10,000 km range)

- Conduct Third World Threat Analysis & Development Timelines
  - Technology assessment
  - Development forecast

- Assess Candidate LRBM Configuration Alternatives
  - Space launch vehicle conversion
  - TBM stacking / clustering

Outline

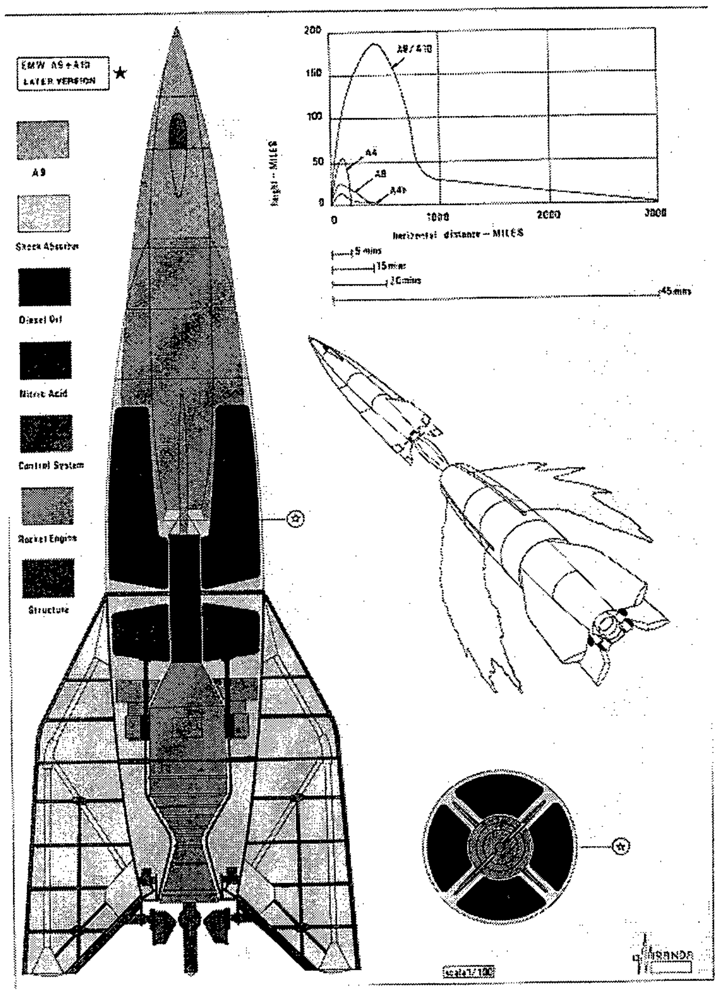
- German WW II Missile Development and Technology Migration
- Trends in Third World Ballistic Missile Weaponry
- Threat Development on a Compressed Schedule
- Candidate LRBM Configurations
- Summary

Key Ingredients of the German Program

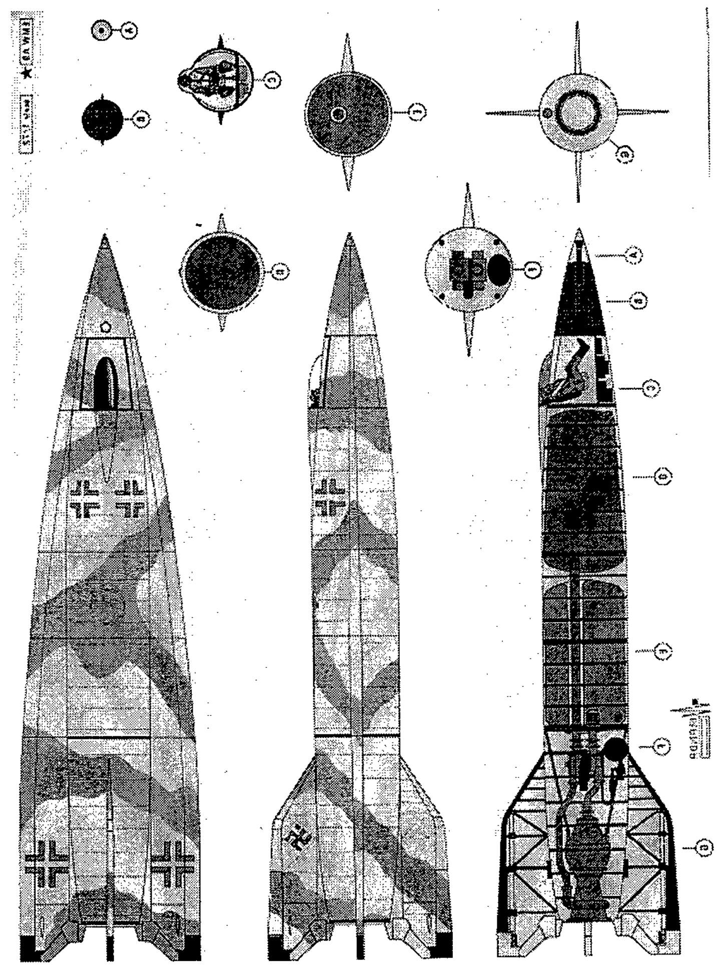
- Political/Cultural Climate
  - Rocket development not constrained by Versailles treaty
  - Autocratic rule
  - Warring factions within the Nazi party for control of ballistic missile program
  - 1920's Weimar Republic had strong interest in rocketry and space flight
  - Use of slave labor
- Technological and Strategic Surprise
  - Early recognition of the value of ballistic missiles for maximizing surprise (1929)
  - Extreme secrecy of the program - first large "black" program
  - Suppression of German amateur rocket societies for security reasons (1933-34)
- Speed of Development
  - National priority / significant funding resources available
  - Excellent domestic industrial skill base to develop required technologies
  - Rapid prototyping using technology demonstrators (Test / Fail / Fix / Re-Test...)

Many of these key ingredients are found in Third World programs today

German Intercontinental Missile Design



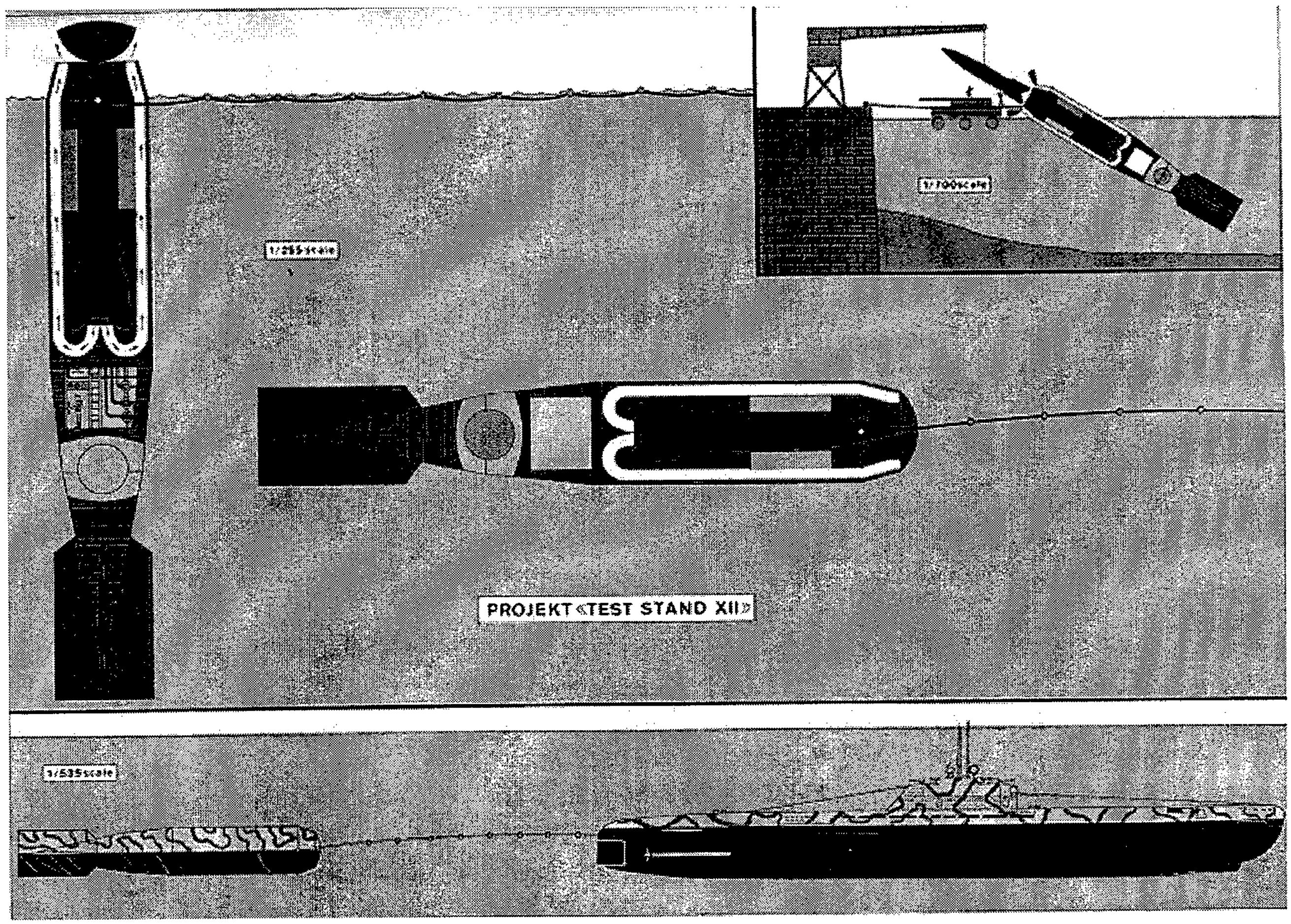
A9/A10



Manned A9

Source: "Secret Wonder Weapons of the Third Reich", J. Miranda, P. Mercado, Schiffer Military/Aviation History, 1996

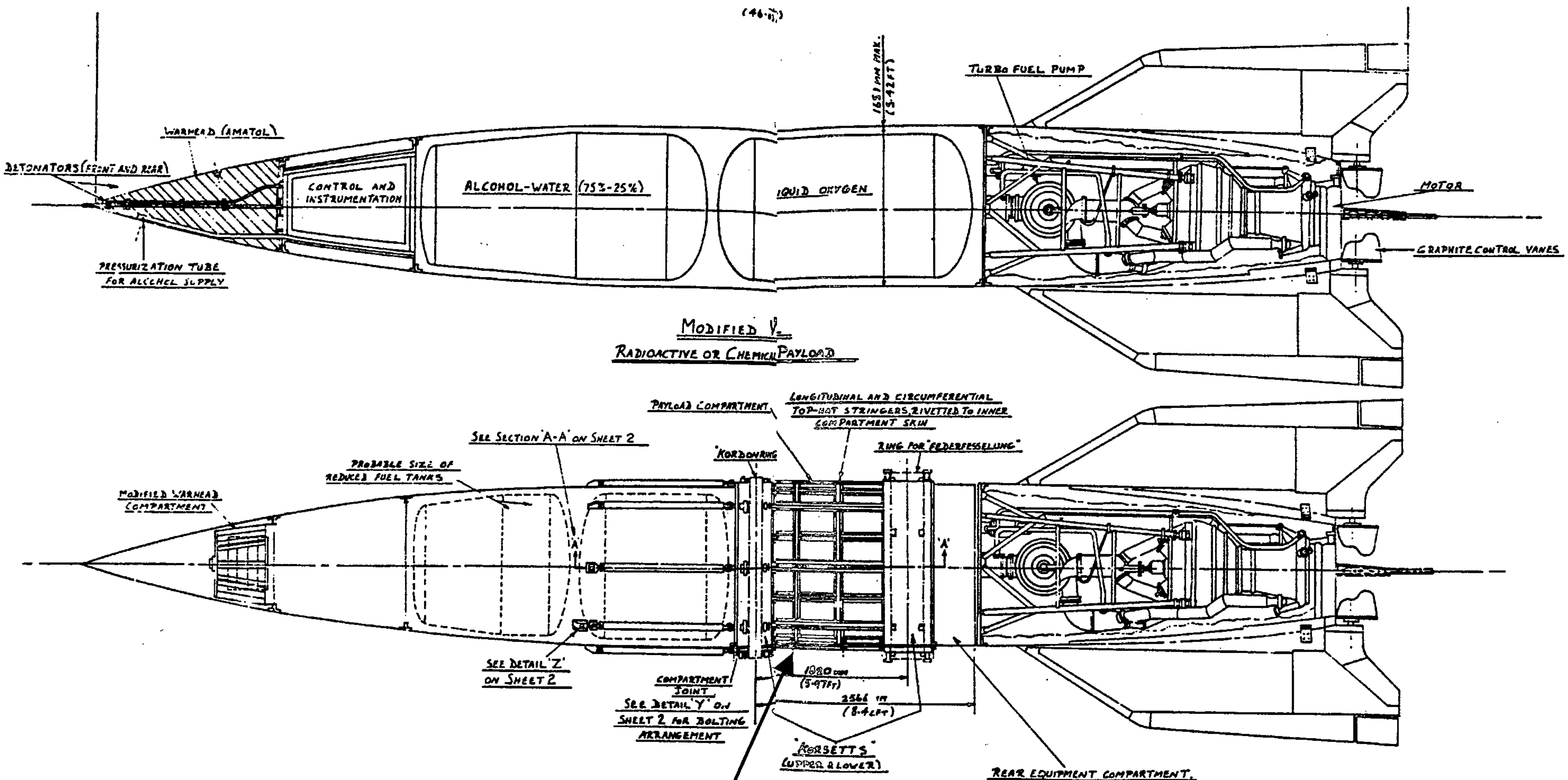
Alternative Concept for Attacking North America



Project Lifevest

Source: "Secret Wonder Weapons of the Third Reich", J. Miranda, P. Mercado, Schiffer Military/Aviation History, 1996

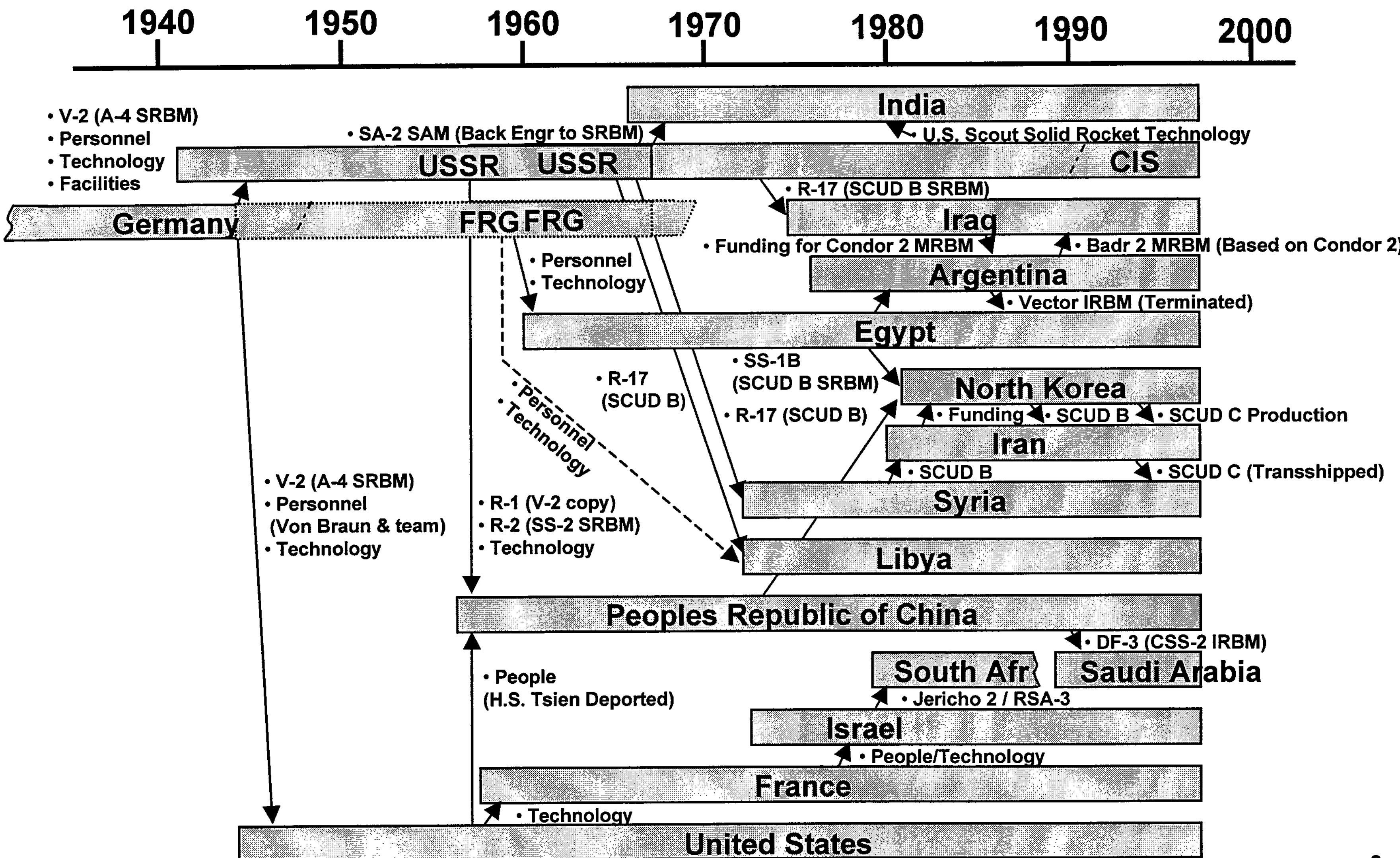
Design for Use of Chemical/Radiological Payloads



Payload Compartment

Source: "Vengeance. Hitler's Nuclear Weapon. Fact or Fiction?", Phillip Henshall, Alan Sutton Publishing Ltd., 1995

Genealogy of Technology Transfer After WW II



International Technology Transfer

	Technology Recipients								
	Israel	India	Egypt	Iraq	Pakistan	Iran	Libya	Saudi Arabia	Syria
Trained Personnel/Advisors	NL, US		AT, DE, ES, CH, SU, US	AR, AT, BE, CL, EG, FR, DE, LI, KP, CN, CH, US, SU	CN	KP	DE	DE, PK, CN, US	
Reentry Vehicles			DE, CH, US SU	CL, EG, FR, DE, LY, US	CN		CL		
Ballistic missile Propulsion				AT, BE, FR, DE, IT, LI, CH, US		CN, KP			CS, IR, IT LY, SU
Guidance/Navigation	ZA, TW US			BR, FR, DE, US		HK, JP		IL, CN	
Flight Controls				BR, DE		HK, JP			
Production Assistance	FR, DE NL, US		AR, DE, KP SA, CH, US	AR, AT, BE, BR, EG, FR, DE, IT, MC, KP CN, CH, GB, US, SU	DE, CN	KP, CN	DE	DE	CS, DE,LY KP, SA,SU
Materials Manufacture			US	DE, LI, GB, US	CA, FR, CH, US				
Computers		US	SA, CH, US	DE	NO, GB			US	
Testing/Ranges	ZA			MR					

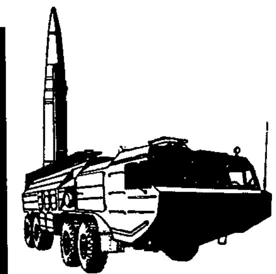
Technology Suppliers

Notes: (1) This information was extracted from the International ballistic missile Proliferation Project database, compiled by the Monterey Institute of International studies under the direction of Dr. William C. Potter and Dr. Edward J. Laurance. It is a compilation of open source material and covers only reports of actual deliveries and transfers since 1989. The table does not include information relating to proposals, offers, negotiations, or orders (unless clear transfers have resulted).

(2) The two-letter codes used in this table are the American National Standard Institute (ANSI) international country codes, defined as follows: AR - Argentina, AT - Australia, BE - Belgium, BR - Brazil, CA - Canada, CH - Switzerland, CL - Chile, CN - China, CS - Czechoslovakia, DE - Germany, EG - Egypt, ES - Spain, FR - France, GB - United Kingdom, HK - Hong Kong, IL - Israel, IR - Iran, IT - Italy, JP - Japan, KP - North Korea, LI - Liechtenstein, LY - Libya, MC - Monaco, MR - Mauritania, NL - Netherlands, NO - Norway, PK - Pakistan, SA - Saudi Arabia, SU - Soviet Union, TW - Taiwan, US - United States, ZA - South Africa.

Iraqi Ballistic Missile Programs

- 1970s -- Iraq receives first Scud-B ballistic missiles from USSR (813 imported by 1990)
- 1982 -- First Iraqi Scud-B attack on Iran
- 3 August 1987 -- Al Husayn tested (500 km range)
- February - April 1988 -- 189 Al Husayn missiles fired in "war of the cities"
- 25 April 1988 -- Al Abbas missile fired on Tehran (860 km)
- 1980-1988 -- Total of 361 Scud-B and Al Husayn missiles fired in Iran-Iraq war
- 5 December 1989 -- Successful launch of Al Abid SLV
- 7 December 1989 -- Tammuz 1 SLV announced (2,000 km range)
- 1991-- Desert Storm saw 88 Al Husayns fired
- 1997 -- Iraq announces Al Hamid ballistic missile (150 km range)



Historical Parallel -- 1930s vs. 1990s

- Missile Technology Control Regime no more effective than Versailles Treaty at limiting technology spread
- MTCR does not "control" anything. Its signers agree to exercise "restraint".
- Ineffective at stopping:
  - Transfer of missiles and components from non-signatory states (e.g., North Korea and China)
  - Emigration of scientists, engineers and technicians
  - Technical education in sciences and engineering which provides missile skills

Outline

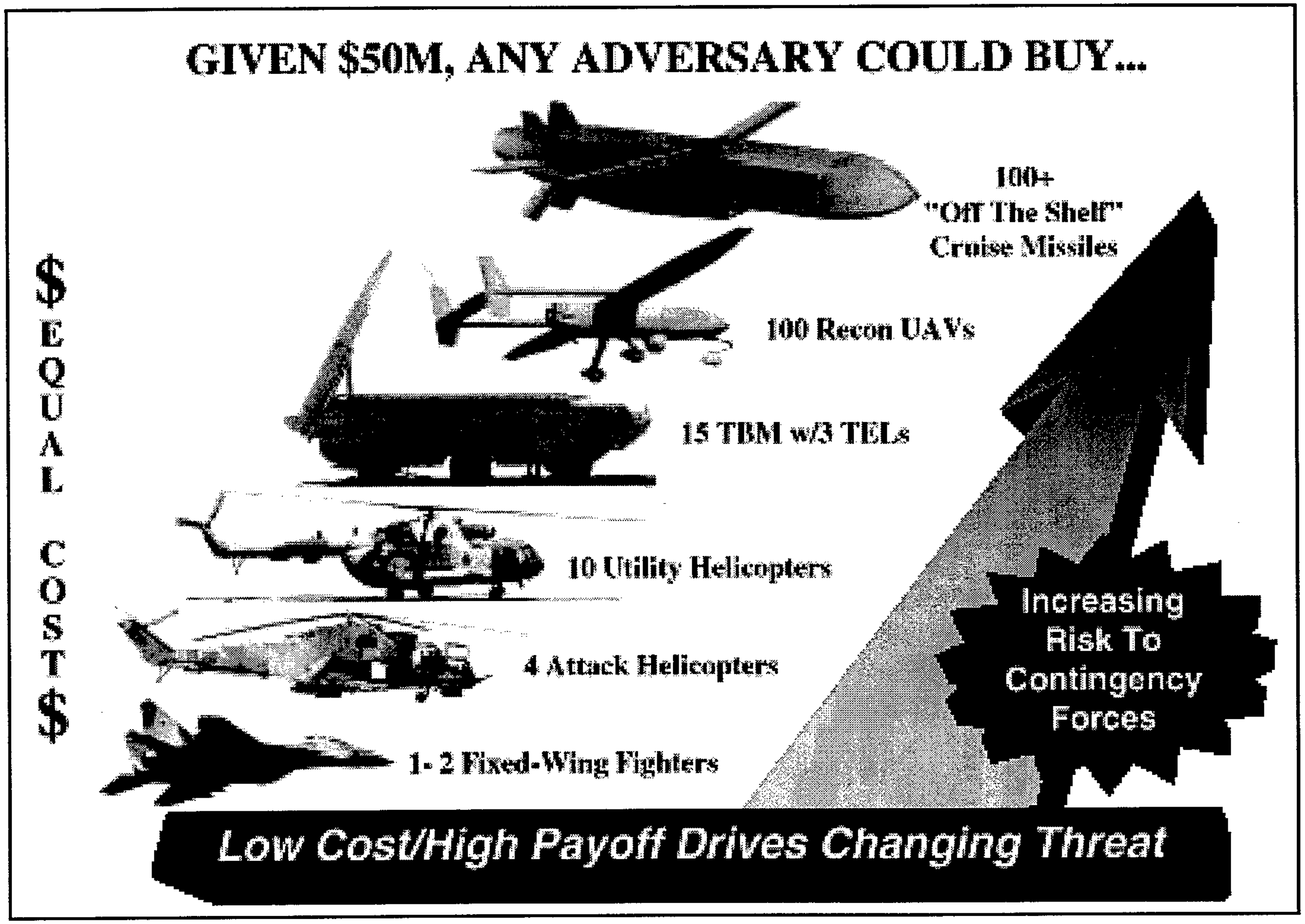
- German WW II Missile Development and Technology Migration
- Trends in Third World Ballistic Missile Weaponry
- Threat Development on a Compressed Schedule
- Candidate LRBM Configurations
- Summary

Third World View of Effective Responses to U.S. Technical Superiority

- Cannot Defeat U.S. / Allies on Battlefield: Land, Sea, Air
  - Persian Gulf War showed failure of direct confrontation
- Development of Hi-tech Conventional Forces Constrained
  - Affordability
  - Technological Availability
  - National Leadership and Power Structures
- Aggressor Nations Must Develop Asymmetric Strategies & Forces to Counter U.S./Allies

Mission	Objective
- Threaten/Attack Population Centers - Threaten/Attack U.S. Forward-Deployed Forces and Allied Bases - Threaten/Attack Air and Sea Ports of Entry - Threaten/Attack Naval and Amphibious Operations	- Prevent Creation and Maintenance of Coalitions - Deny Facilities/LOC's to U.S./Allies - Prevent Entry of U.S./Allied Forces - Raise Risk to Unacceptable Levels

MISSILES -- Cost-Effective Force Decision

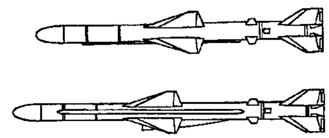


Source: US Army ADA School, Air and Missile Defense Master Plan (threat section), September 1996

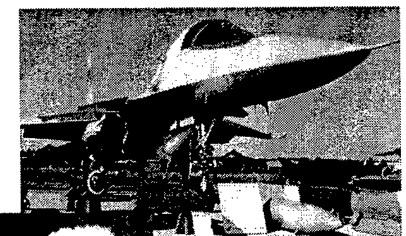
MISSILES -- Third World Weapons of Choice

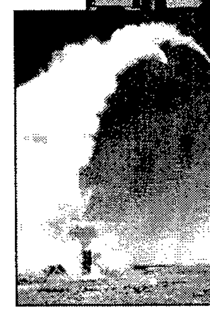
- Robust Force Structure
  - Cruise and Ballistic missiles
  - Integrated Air Defense Systems
  - Aircraft with long-range missiles
- Missiles -- Most Cost Effective Investment
  - High speed improves penetration of defenses
  - Onboard seekers & GPS guidance for accuracy
  - WMD delivery meets military/political goals
  - Existing technology conceals development
- Improved Targeting
  - Increased access to space surveillance
  - Modern mobile communications coordinate dispersed launches
  - Computer flight planning allows pre-programmed attack profiles
  - GPS navigation updates enables cheap precision

C-801, -802

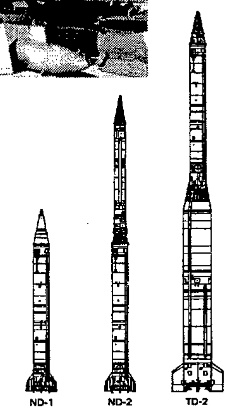


Su-34 & Missile Armaments



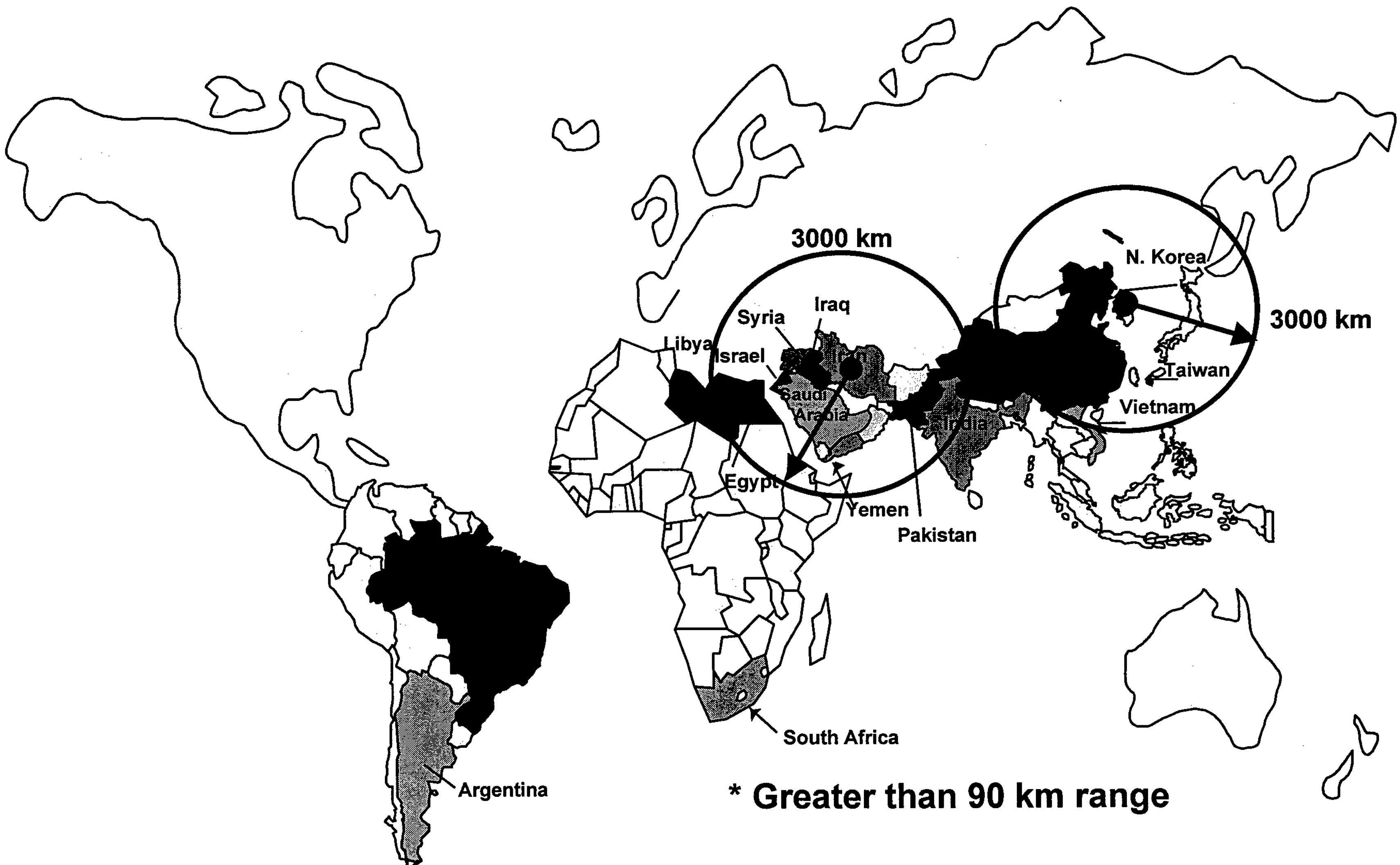


SA-15 Launch



North Korean Ballistic Missiles

Third World Countries with Ballistic Missiles *



* Greater than 90 km range

Third World Indigenous Capabilities

		Israel	India	Egypt	Iraq	Pakistan	Iran	Libya	Saudi Arabia	Syria
Human Resources		Substantial	Substantial	Modest	Modest	Modest	Modest	Rudimentary	Rudimentary	Rudimentary
Technical Resources	Ballistic missiles	Substantial	Substantial	Modest	Modest	Modest	Modest	Rudimentary		
	Space	Substantial	Substantial		Rudimentary	Modest				
	Artillery	Substantial	Substantial	Modest	Modest		Rudimentary			
	Ordnance	Substantial	Substantial	Substantial	Modest	Modest	Modest	Modest	Rudimentary	Modest
	Aircraft	Substantial	Substantial	Modest	Rudimentary	Modest	Rudimentary			
	Electronics	Substantial	Substantial	Rudimentary	Modest					
Test Resources		Substantial	Modest	Rudimentary	Rudimentary	Modest		Rudimentary		

Substantial capability:
- Large numbers of experts and technicians
- Indigenous manufacturing
- Instrumented test ranges

Modest capability:
- Some experts and technicians
- Spare parts manufacturing
- Component test/ground test

Rudimentary capability:
- Few experts or technicians
- Repair and refurbishment
- Limited test facilities

Reference: "Rest of World (ROW) Response to GPALS: Technology and Industry Bases", Strategic Defense Initiative Organization, June 1992

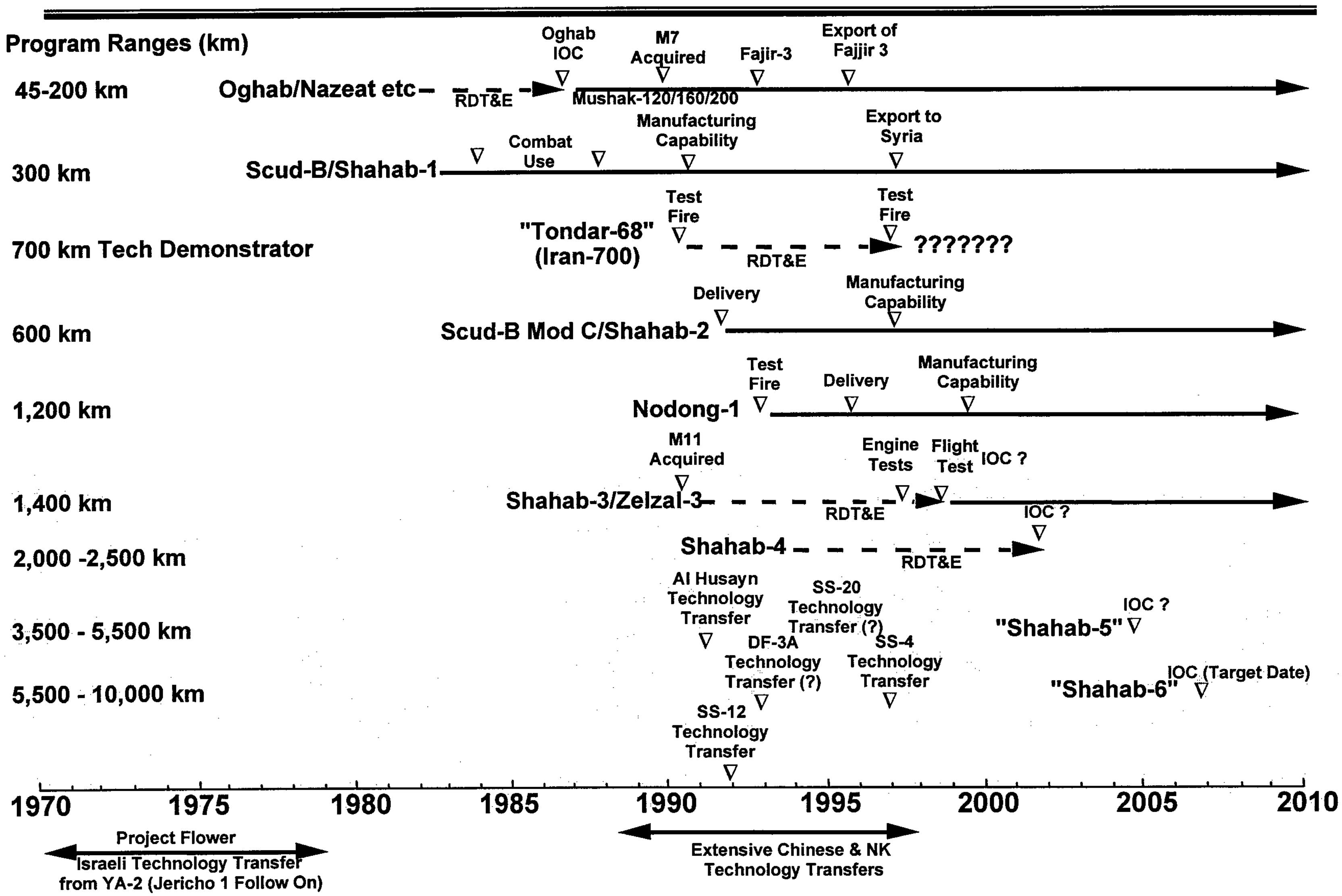
Current Third World Ballistic Missile Capabilities

Country	Missile System	Status	Propulsion	Launch Weight (kg)	Payload Weight (kg)	Range (km)
China	CSS-1 (DF-2A)	1966 IOC	L	26,000	1500	1250
	CSS-2 (DF-3)	1971 IOC	L/L	64,000	2000	2650
	CSS-2 (DF-3A)	1986 IOC	L/L	64,000	2150	2800
	CSS-3 (DF-4)	1978 IOC	L/L	82,000	2200	4750
	CSS-4 (DF-5A)	1986 IOC	L/L	183,000	3200	13000
	CSS-5 (DF-21A)	1987 IOC	L/L	14,700	600	1800
	DF-25	Reported Stopped	S/S/S		2000	1700
	DF-31	1996 IOC	S/S/S		700	8000
	DF-41	Under Dev.	S/S/S		800	12000
India	Agni I	Flight Tested	S/L	16,000	1000	>2000
	Agni II	Dev. Initiated	S/S		1000	3000
Iran	Shihab 3	Flight Tested	L		750	1700
	Shihab 4	Early Stages of Dev.	S		1000	3000
	Shihab 5	Engaged Effort				3000+
	Labour 1 (No Dong 1 import)		L			
	Labour 2 (No Dong 2 joint effort)	In Dev.	L/L			

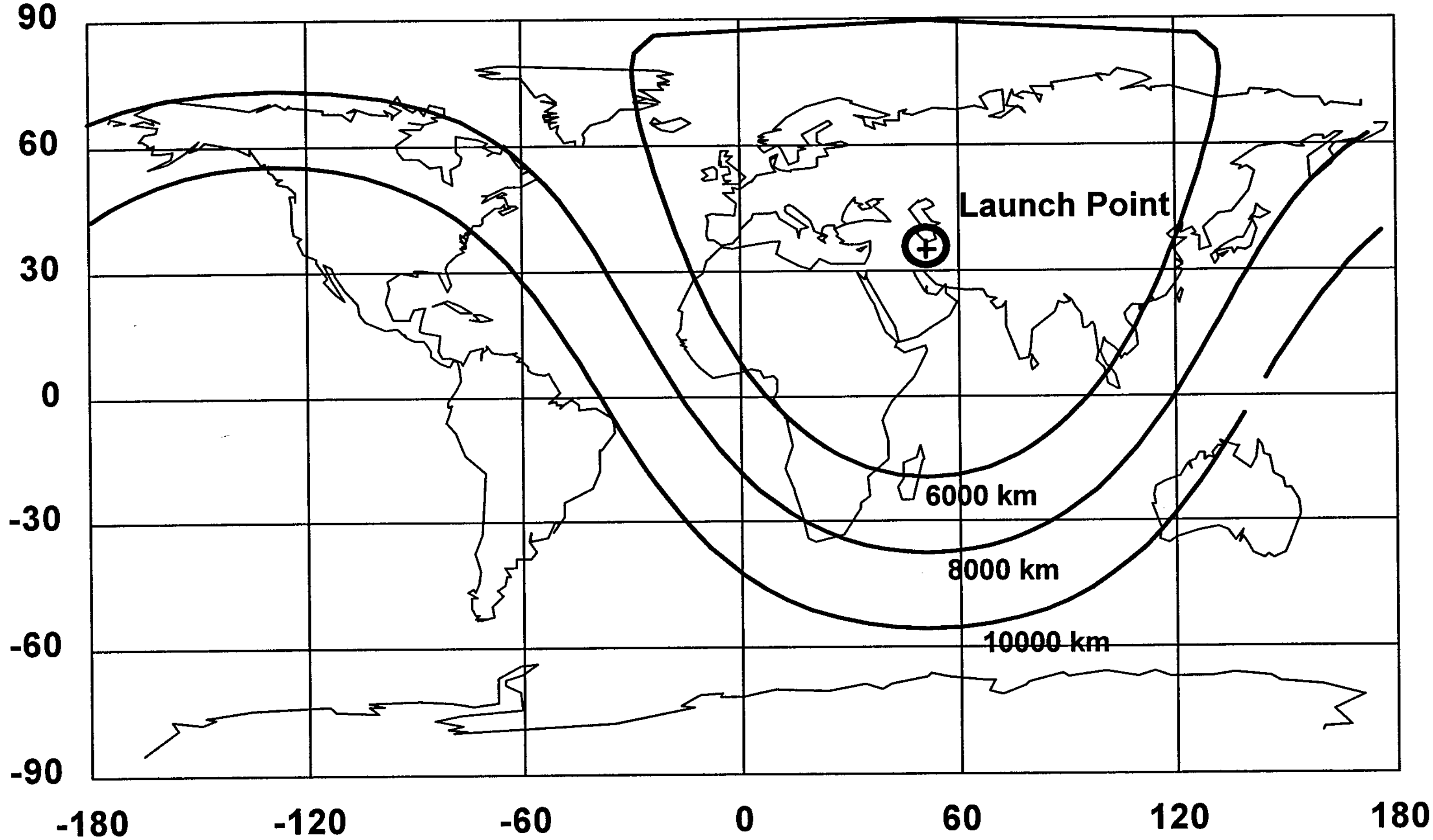
Current Third World Ballistic Missile Capabilities (Cont)

Country	Missile System	Status	Propulsion	Launch Weight (kg)	Payload Weight (kg)	Range (km)
Iran (cont.)	Tondar 68 (Iran 700)	Dev. Prototype	L or S		500	700-1000
	Zelzal –3 (modified M-11)		S			1000-1500
	M-18 (import form China)		S			700-1000
Iraq	Al Abid	Dev. Cancelled	L/L	48,000		2000
	Tammuz 1	Dev. Cancelled			750	2000
	Badr 2000	Dev. Cancelled (Joint Iraq, Egypt,Argentina effort)			450	900
Israel	Jericho 2B (YA-2B)		S/S			1300
	Jericho 3	1990 IOC	S/S	29,000	1000	4800
North Korea	NoDong 1 (aka Rodong-1)	Flight Tested	L	21,000	800	1300
	Taepo Dong 1 (aka No Dong 2, Rodong-2)	In Dev. / Poss. 1 Flt Test	L/L	21,000	1000	1500-2000
	Taepo Dong 2	Engaged Effort	L/L		1000	3,500-6000
Pakistan	Ghauri/Mk III	One flight test	L		500-750	1500
Saudi Arabia	CSS-2 (imported from China)	1988 IOC	L	65,200	1900	3100

Iran's Ballistic Missile Development Program

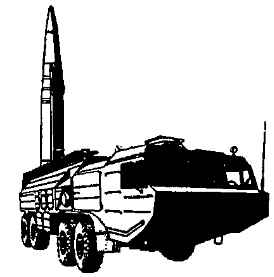


Potential Iranian LRBM Coverage

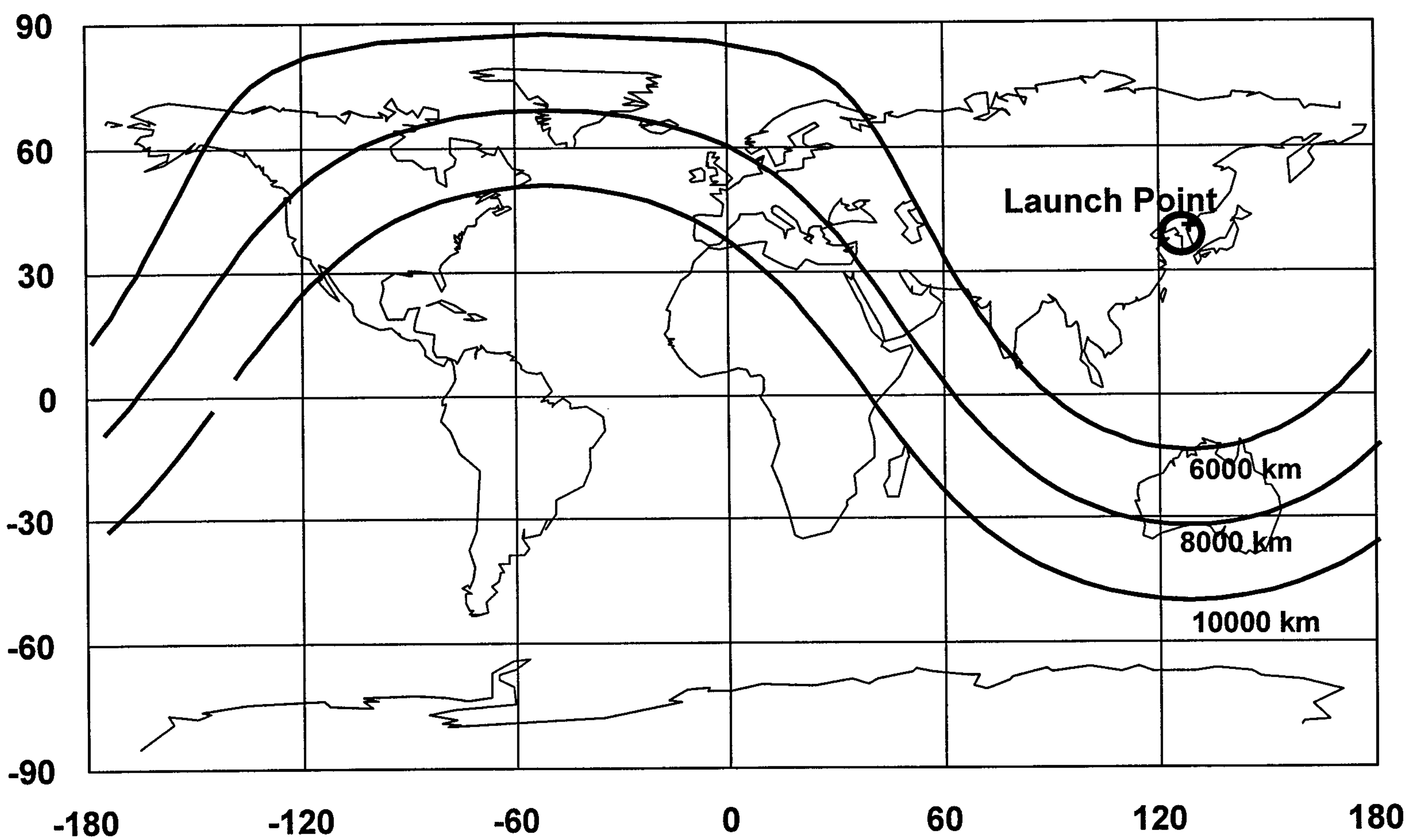


North Korean Ballistic Missile Programs

- 1975 ~ DF-61 Program with China Terminated
- 1981 ~ Egypt Supplies Scud-B Missiles for Evaluation
- 1984 ~ Scud-B Mod A Tested
- 1985 ~ Scud-B Mod B Tested
- 1987 ~ Scud-B Mod B Exported to Iran
- 1989 ~ Scud-B Mod C Deployed
- 1990 ~ Nodong-1 Program Underway
- 1993 ~ Nodong-1 Tested
- 1995 ~ Taepo Dong 1 and 2 Programs Underway
- 1996 ~ Nodong-1 Exported to Iran
- 1998 ~ Nodong Technology in Pakistani Ghauri
- 1998 ~ Potential Space Launch/LRBM Capability



Potential North Korean LRBM Coverage



Outline

- German WW II Missile Development and Technology Migration
- Trends in Third World Ballistic Missile Weaponry
- Threat Development on a Compressed Schedule
- Candidate LRBM Configurations
- Summary

Overcoming Challenges to Third World LRBM Development

Obvious limitations...

- Access to Critical Technologies -- MTCR and economic sanctions
- Engineering and manufacturing infrastructure -- old facilities
- Missile system integration skills -- limited technical manpower

... mitigated by innovative shortcuts:

[redacted]

Key Technical Challenges

- Propulsion Systems
  - Liquids
    - Ground handling and loading of propellants -- toxicity & volatility
    - Valves and flow control for predictable burnout
  - Solids
    - Propellant grain consistency (motor-to-motor)
    - Dangerous large grain mix, pour, and cure
- Structures
  - Design, fabrication, and assembly of truss structures and interstages
  - Cluster/stack integration
  - Dynamic load margins throughout flight
- Control Electronics
  - Accurate navigation, timing, sensing of booster variations
  - Staging
  - Power supplies and thermal control for LRBM duration flight

Key Technical Challenges (Cont)

- Reentry Systems
  - ➡ Payload packaging for high deceleration shock loads
  - Stable dynamic shape design and balancing techniques
  - Thermal protection against heating loads at LRBM reentry velocities
  - ➡ Fusing for payload detonation/dispersal at desired altitude
- System Test and Verification Technology
  - Onboard system performance instrumentation
  - Telemetry electronics and antennas (ballistic missile and range)
  - Flight data analysis tools

13 Critical Technologies

- High Energy Propellants
- Light Weight Subsystems
- Dynamic Structures Design and Analysis
- Aerodynamic Heat Protection Materials
- Advanced Flight Dynamics Control Systems
- Multi-Stage Separation and Ignition
- Payload Separation and Stabilization
- Payload Reentry Survival
- Warhead Fusing
- Guidance and Control Computers
- GPS/INS Platforms
- Flight Test Tracking and Telemetry
- High Fidelity Computer Simulation

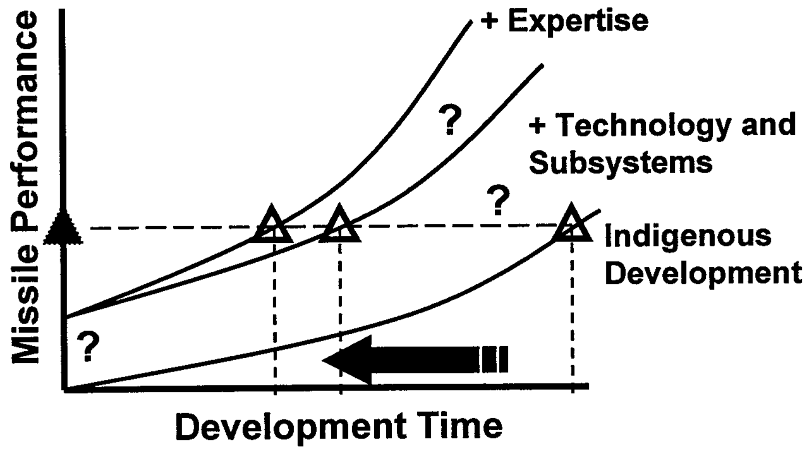
Required Engineering Infrastructure

- Technical Expertise
  - System design engineering
  - Fabrication methods
  - Materials & processes
  - Flight mechanics
  - Guidance & control
  - Modeling & simulation
- Flight Test
  - Range size and access
  - Range instrumentation
  - Data analysis
- Industry
  - Propellant processing and handling
  - Propulsion subsystems
  - Electro/mechanical control systems
  - Structures manufacturing/assembly
  - Materials processing
  - Electronics production
  - Precision guidance fab. & assembly
  - Computer hardware and software

Home-Grown or "Contracted" Foreign Assistance Satisfies Required Development Functions

Third World Development Time Compression

Accelerating Missile Development



Desired Missile Capability ▲ can be attained by a combination of development "investments" that may be hard to identify

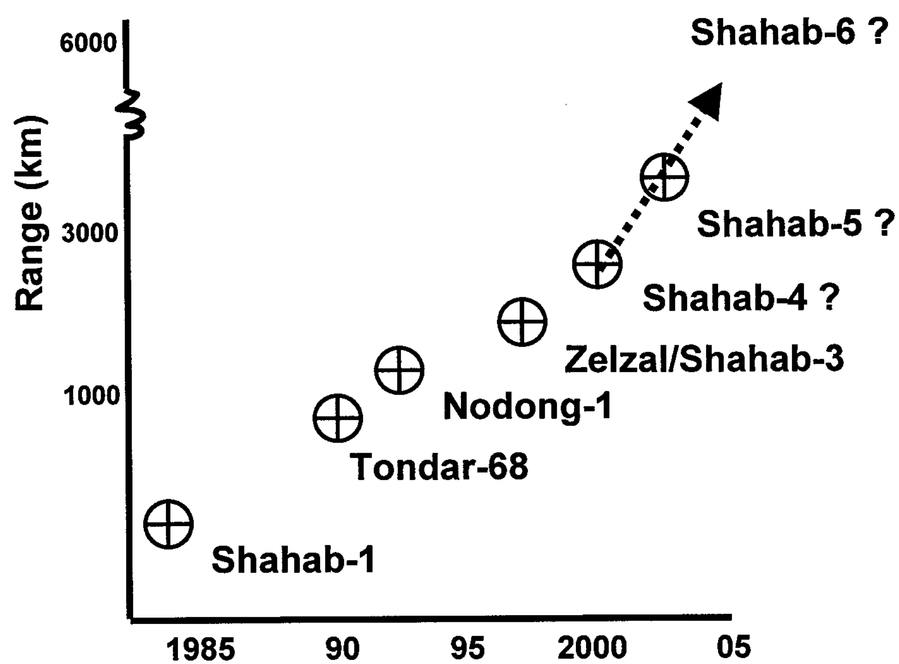
? Critical Unknowns:

1) Level of missile technology at "start point"

2) Foreign assistance to expedite system integration of acquired components

Iran's Missile Program Evolution

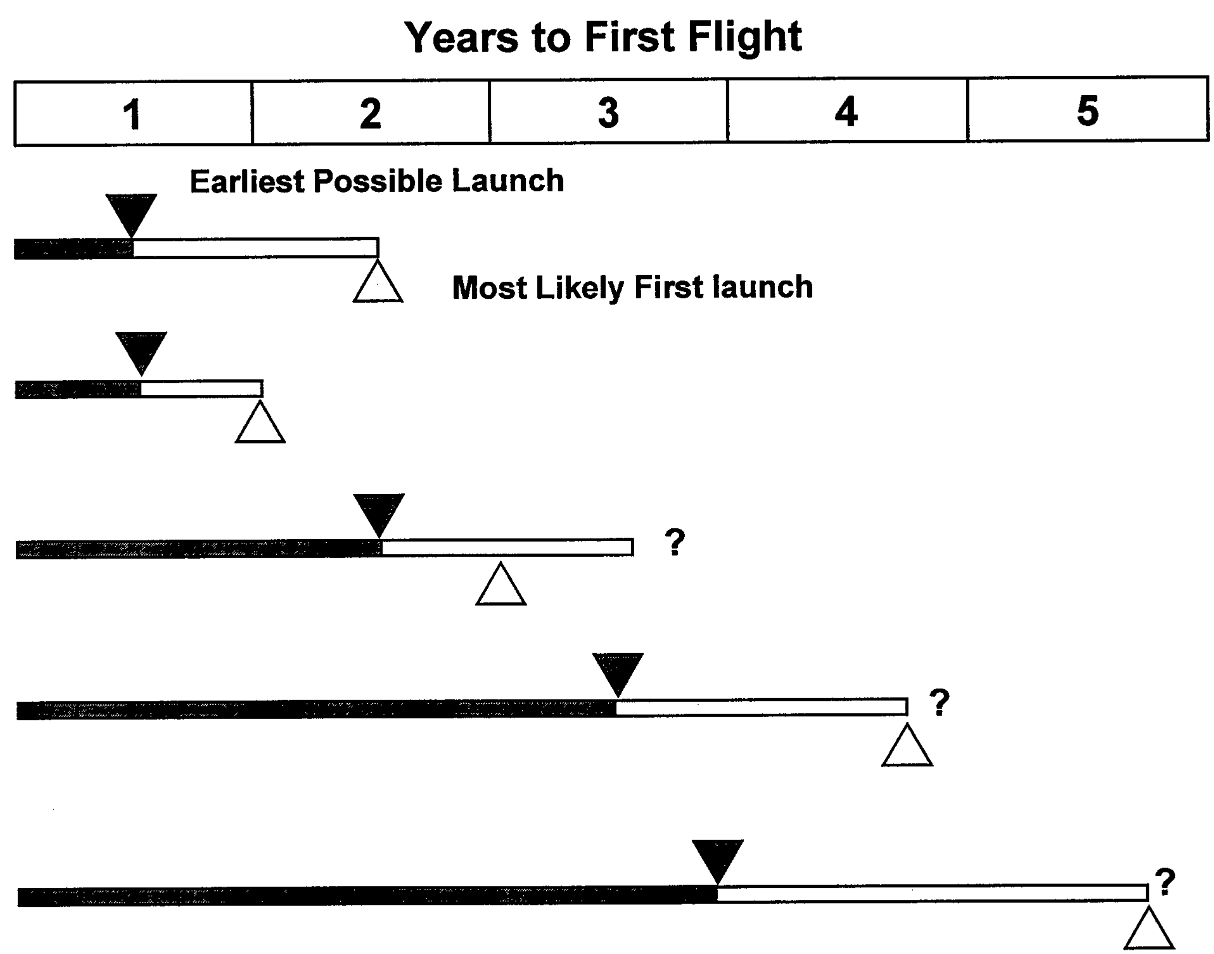
- Combines imported systems with indigenous development and testing
- Extensive use of foreign expertise
- Steady range growth beyond regional requirements



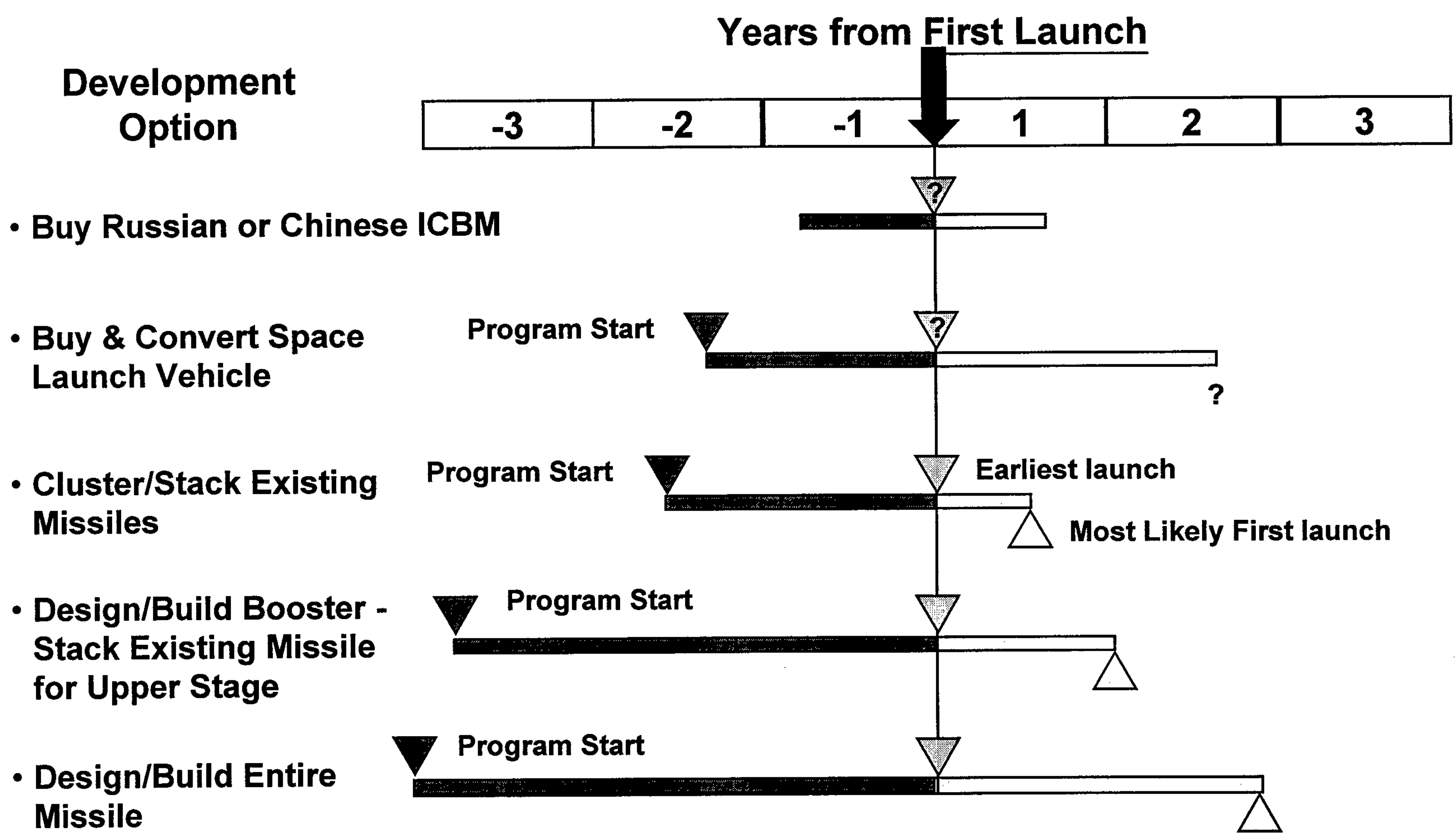
Development Time Estimate

Development Option

- **Buy Russian ICBM**
- **Buy & Convert Space Launch Vehicle**
- **Cluster/Stack Existing Missiles**
- **Design/Build Booster - Stack Existing Missile for Upper Stage**
- **Design/Build Entire Missile**



Effective Time to Respond



[redacted]

Outline

- German WW II Missile Development and Technology Migration
- Trends in Third World Ballistic Missile Weaponry
- Threat Development on a Compressed Schedule
- Candidate LRBM Configurations
- Summary

Options for LRBM Development

- Buy LRBM (MRBM, IRBM, ICBM)
- Buy & Convert Space Launch Vehicle
- Cluster/Stack Existing Tactical Missiles
- Design/Build Booster - Stack Existing Missile for Upper Stage
- Design/Build Entire Missile

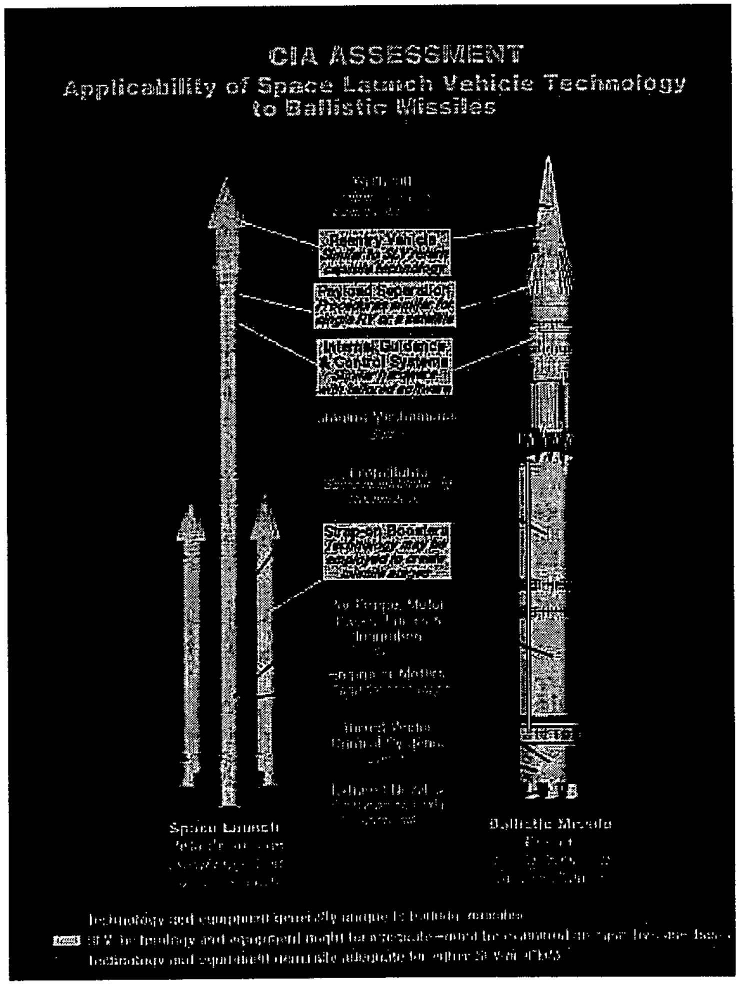
Available IRBMs

Missile	Payload(kg)	Range(Km)	Warhead	Country	IOC
• DF-3/DF-3A	2000/ 2150	2800	Conv./ NBC	China	1971/ 1986
CSS-2	1900	3100	Conv.	Saudi Arabia	1988
• CSS-3	2200	4750	Conv./ NBC	China	1978
• DF-25	2000	1700	Conv./ NBC	China	Dev. Stop 1996
• Agni 1	1000	2000	Conv.	India	1998
• Agni 2	1000	3000	Conv./ NBC	India	2002?
• Shahab 4	1000	3000	Conv./ NBC	Iran	2002
• Shahab 5	?	?	Conv./ NBC	Iran	2005?
• Jericho 3	1000	4800	Conv./N?	Israel	2000?
• TD-1	1000	1500-2000	NBC	N.Korea	1998?
• TD-2	1000	2000-4000	NBC	N.Korea	1998?

Options for LRBM Development

- Buy LRBM (MRBM, IRBM, ICBM)
- Buy & Convert Space Launch Vehicle
- Cluster/Stack Existing Tactical Missiles
- Design/Build Booster - Stack Existing Missile for Upper Stage
- Design/Build Entire Missile

CIA Assessment of SLV-LRBM Conversion



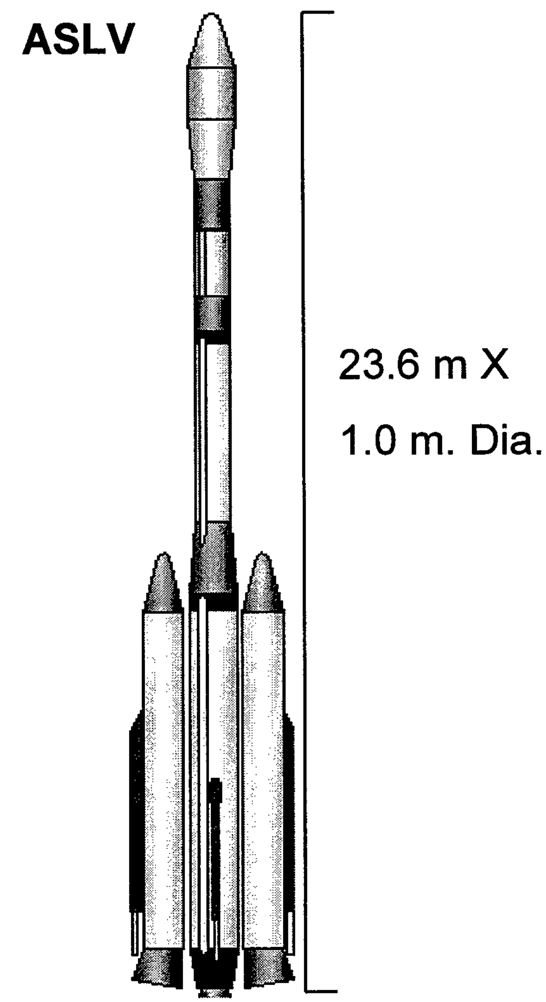
- Only <u>unique</u> ballistic missile technology is the warhead
- RV, separation, guidance & control, and strap-on booster SLV technologies may be <u>adequate</u>
- Staging, propellants, airframe, engines, thrust control, and nozzles are the <u>same</u> as SLV

Figure from 5/14/98 CIA briefing; as depicted in *Aviation Week & Space Technology*, June 1, 1998.

Indian ASLV Conversion

- Propulsion Configuration
  - 4-stage solid propellant booster (SLV-3)
  - 2 strap-on rocket motors
- Space Launch Capability
  - Launch weight 39,000 kg
  - Payload weight 150 kg
  - Orbit altitude 400 km
  - Inclination 46 degrees
- Ballistic Missile Capability
  - Launch weight 40,000 kg
  - Payload weight 1000 kg
  - Range (NRE) 4,000 km

From Jane's Information Group



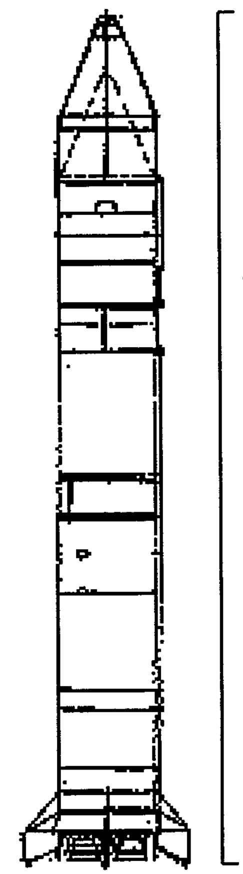
Drawing from Federation of American Scientists:
http://www.fas.org/spp/guide/india/launch/aslv.htm

Israeli SHAVIT Conversion

- Propulsion Configuration
  - 3-stage solid propellant booster (based on Jericho 2)
  - NEXT, slightly larger follow-on
- Space Launch Capability
  - Launch weight 29,000 kg
  - Payload weight 800 kg
  - Orbit altitude 400 km
  - Inclination Polar
- Ballistic Missile Capability
  - Launch weight 29,000 (est.)
  - Payload weight 1,100 kg
  - Range (NRE) 5,000-7,000 km

From Jane's Information Group

SHAVIT SLV



14 m. X

1.56 m. dia.

- Demonstrated 160 kg payload to 207 x 1587 km elliptical orbit @ 143 degree retrograde inclination.

Jerico 2 From Federation of American Scientists web site:
http://www.fas.org/spp/guide/Israel/launch/index.htm

Japanese M-3 or M-5 Conversion

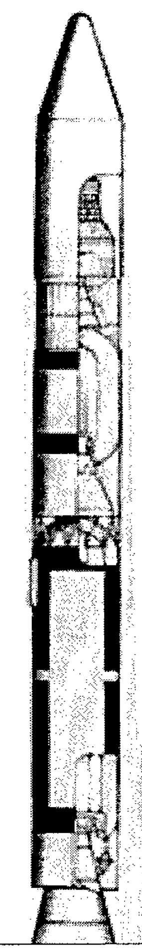
- The M-3 space launch vehicle "family" could be converted into an IRBM with a 500+ kg payload and a range of 4,000+ km. The Japanese Government has officially refuted this allegation. *

- The M-5 is a three- or four-stage, solid propellant launch vehicle designed to carry payloads of 2,000 kg to 200 km; 1,200 kg to 500 km and 800 kg to GTO. *
- Three-stage version shown:
  - Length = 31.0 m
  - Diameter = 2.5 m
  - Launch weight = 130,000 kg

M-5 LRBM performance has not yet been assessed

From Jane's Information Group

M-5 SLV



9 m.

Insulated payload faring &

Third stage w/ ENEC & TVC

6.7 m

2nd stage w/ ENEC & TVC

13.7 m

1st stage w/ movable nozzle

Source: Jane's Strategic Weapons

Options for LRBM Development

- Buy LRBM (MRBM, IRBM, ICBM)
- Buy & Convert Space Launch Vehicle
- Cluster/Stack Existing Missiles
- Design/Build Booster - Stack Existing Missile for Upper Stage
- Design/Build Entire Missile

Two Feasible LRBM Designs

Liquid

- Clustered CSS-2 ballistic missiles
  - Stage 1 -- 3 CSS-2's
  - Stage 2 -- 1 CSS-2

  (Separate at burnout)

Payload -- 1000 kg
Guidance -- 150 kg
Launch Weight -- 255,400 kg
Reentry Angle -- 30 degrees
Time of Flight -- 46.5 minutes
Range -- 10,000 km

Solid

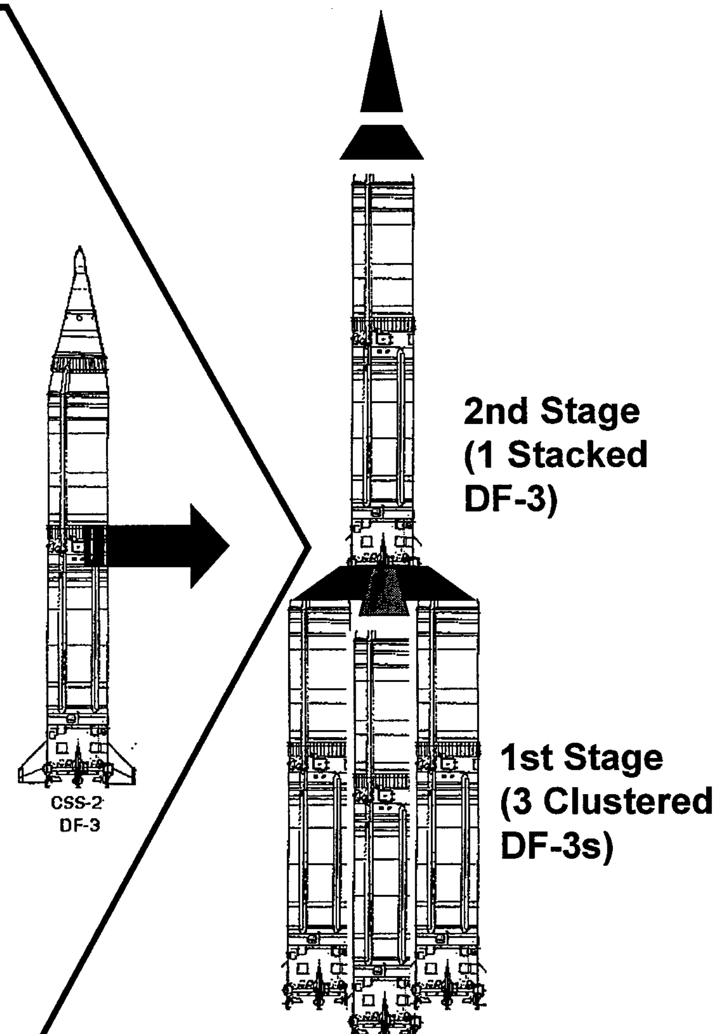
- Clustered M-9 ballistic missiles
  - Stage 1 -- 7 M-9's
  - Stage 2 -- 3 M-9's
  - Stage 3 -- 1 M-9

  (Separate at burnout)

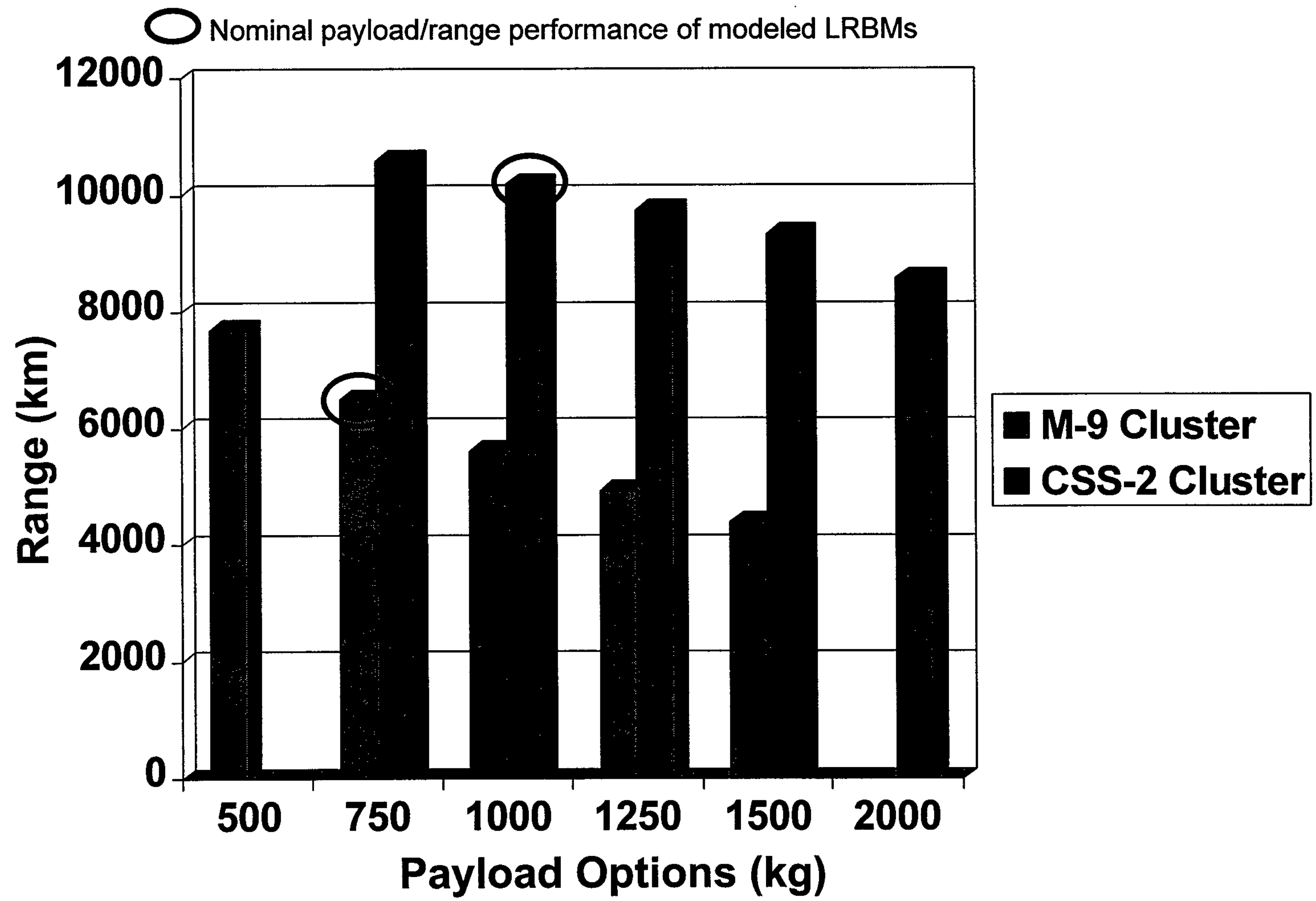
Payload -- 750 kg
Guidance -- 150 kg
Launch Weight -- 59,000 kg
Reentry Angle -- 30 degrees
Time of Flight -- 28.5 minutes
Range -- 6,500 km

Design Issues Considered in Assessment

- RV structure & materials for 30 degree reentry
- Payload separation at booster burnout; G&C stays with spent upper stage
- Interstages between booster stages sized for flight loads at increased diameter
- Revised raceways and electrical system wiring
- Guidance subsystem increased power and cooling
- Truss structure for clustered rocket motors
- Extendible nozzle exit cones (upper stages only)
- Booster separation mechanisms
- Booster thermal protection for aero loads and motor nozzle heat



Range Sensitivity to Payload Weight



Evaluation Methodology

- AS-2530 Flight Simulation Code
  - 3 - degrees of freedom
  - Non-rotating spherical earth
  - Standard atmospheric properties
- Powered ascent flight profile
  - Vertical launch
  - Instantaneous pitchover
  - Gravity turn
  - Payload separation at booster burnout
- Payload flight profile
  - Keplarian free flight
  - Keplarian reentry
  - No reentry angle of attack
- Missile characteristics
  - Nominal ballistics
  - Nominal weights
  - Estimated drag properties

Outline

- German WW II Missile Development and Technology Migration
- Trends in Third World Ballistic Missile Weaponry
- Threat Development on a Compressed Schedule
- Candidate LRBM Configurations
- **Summary**

Summary

- Third World Countries *are* capable of achieving LRBM capability
- Innovative technical shortcuts may be used for different national goals
  - Political or coercive vs military capability
- Time to First Flight may be much earlier than currently anticipated
- Time from observed threat to first launch may be *very* short
- MTCR is not stopping missile technology proliferation
- Developed countries are currently marketing critical ballistic missile technologies, systems, and personnel

The Time Between Inescapable Evidence of a Developing Threat to When That Threat is Fielded May be Less Than the Time in Which We Can Respond