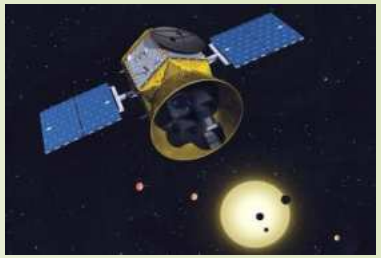
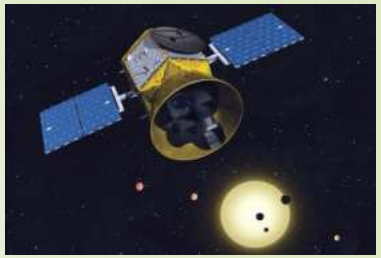
CYBER SECURITY IN NEW SPACE



SPACE (OLD & NEW) A PERSPECTIVE

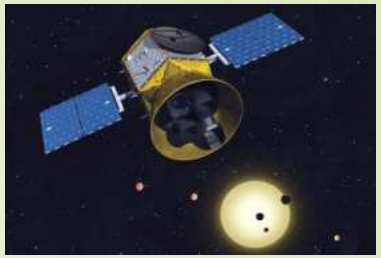
- OLD SPACE – COLD WAR ERA PRACTICES & SPACE APPLICATIONS
- NEW SPACE
  - AGILITY PATTERN BORN FROM INCORPORATING STANDARD MODULES AND COMPONENTS WHILST MAKING SPACE TRAVEL CHEAPER AND MORE WIDE SPREAD ACROSS INDUSTRIES IS CHARACTERIZED BY THE TERN ‘NEW SPACE’

SCOPE



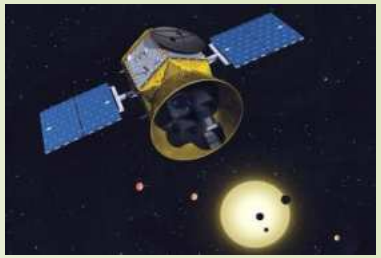
- MAJOR APPLICATIONS OF NEW SPACE
- SATELLITE ARCHITECTURE & SPACE SYSTEM ARCHITECTURE
  - SATELLITE LIFE CYCLE
  - SPACE & SATELLITE SYSTEMS & SPACE SEGMENT ARCHITECTURE
  - SATELLITE CONSTELLATIONS
  - GROUND SEGMENT ARCHITECTURE

SCOPE



- THREATS TO SPACE SYSTEM & SECURITY RELATED INCIDENTS
  - GROUND SEGMENT
  - COMMUNICATIONS
  - SPACE SEGMENT
  - REGULATORY REQUIREMENTS
  - REVIEW & ANALYSIS OF SATELLITE INCIDENTS

SCOPE



- KEY ENABLING TECHNOLOGIES IN NEW SPACE
  - SMALL SATELLITE CLASSIFICATIONS
  - GROUND SEGMENT
  - SPACE PROTOCOLS & THEIR SECURITY
  - USER SEGMENT
  - CRYPTOGRAPHY FOR THE NEW SPACE
- OPEN CHALLENGES FOR SPACE & SATELLITES
- CONCLUSION

MAJOR APPLICATIONS OF NEW SPACE

- EARTH OBSERVATION MARKET
- GLOBAL BROADBAND SERVICES
- SATELLITE GEO LOCATION SERVICES
- MUNITIONS & WEAPON TECHNOLOGY

SATELLITE LIFE CYCLE & SPACE SYSTEM ARCHITECTURE

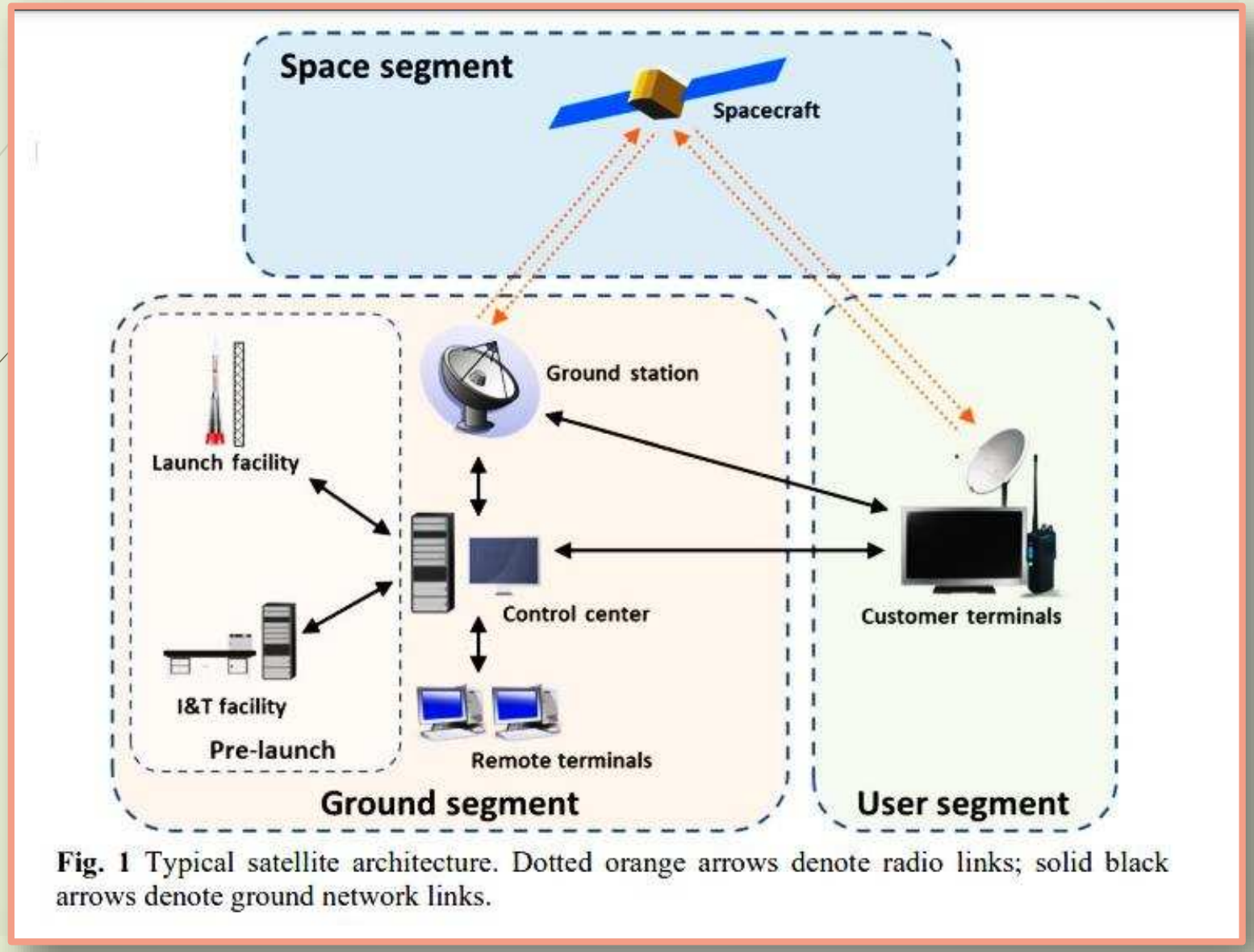
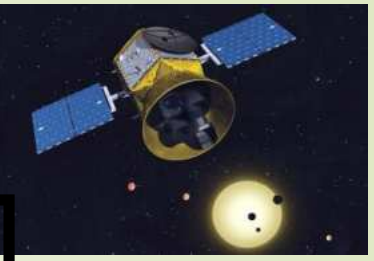
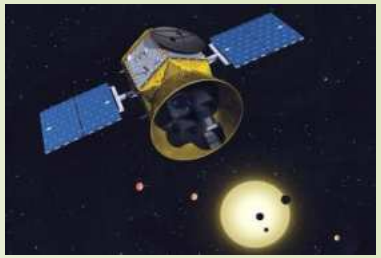


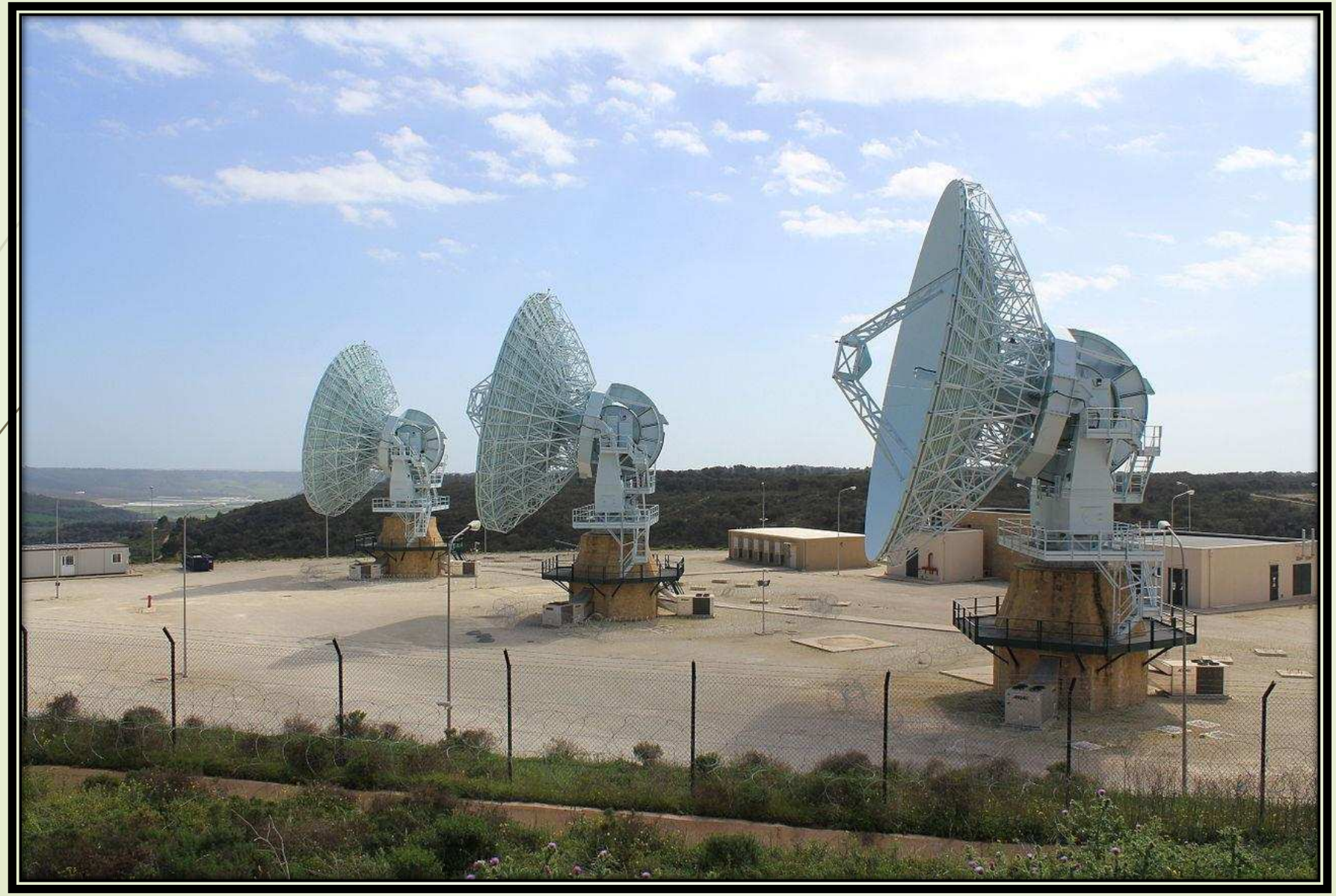
Fig. 1 Typical satellite architecture. Dotted orange arrows denote radio links; solid black arrows denote ground network links.

SATELLITE LAUNCH PAD

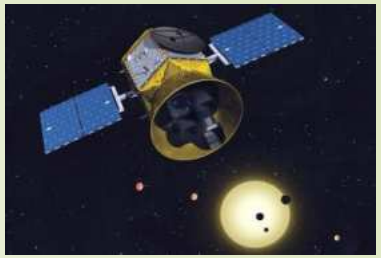


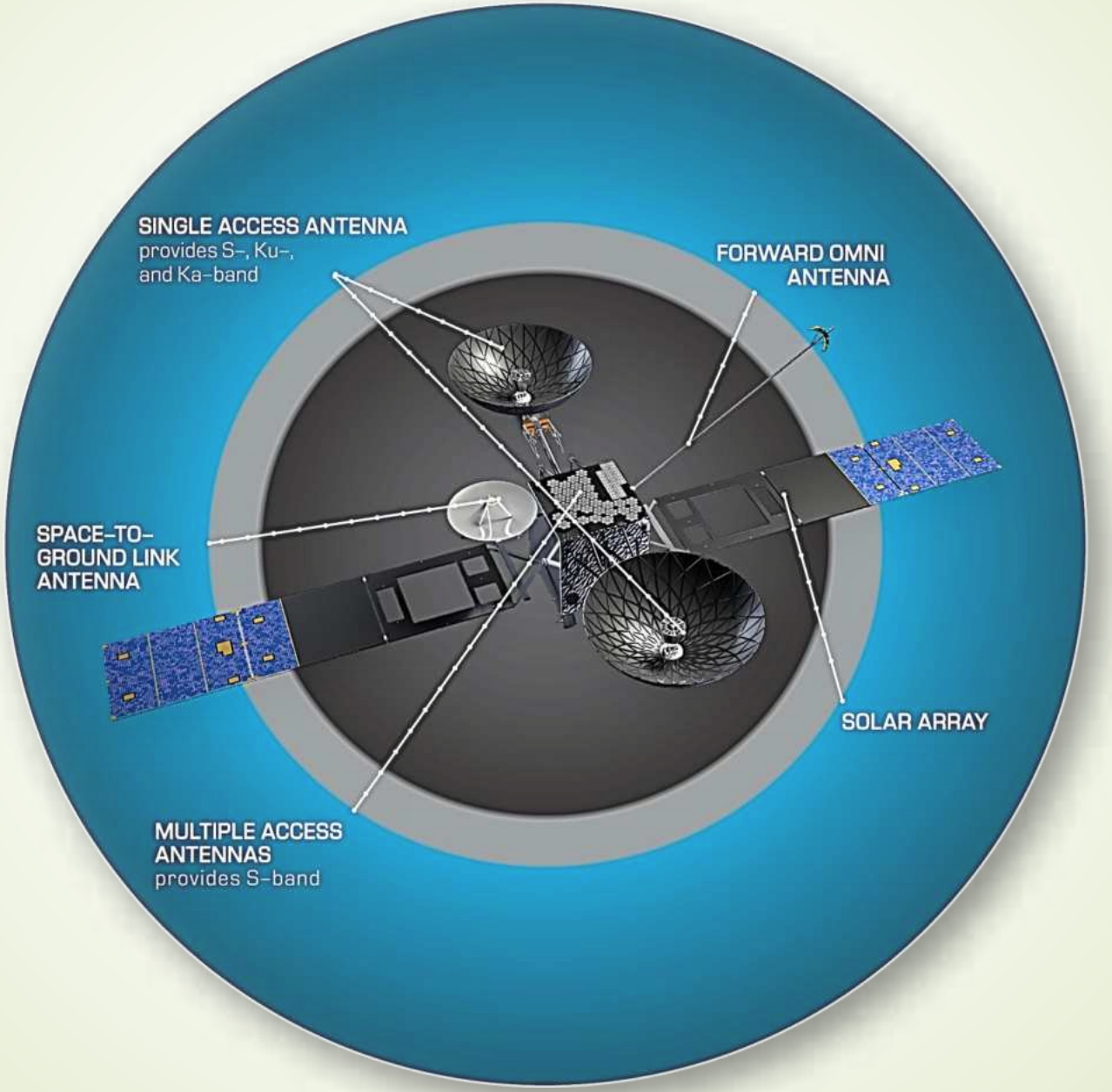
SATELLITE GROUND DATA TERMINAL



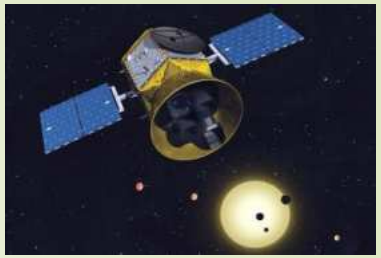


SATELLITE



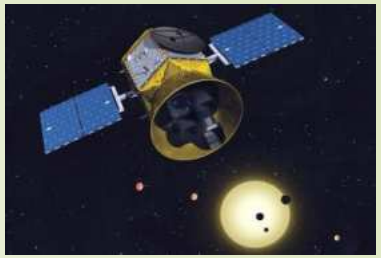

SINGLE ACCESS ANTENNA
provides S–, Ku–,
and Ka–band
FORWARD OMNI
ANTENNA
SPACE–TO–
GROUND LINK
ANTENNA
SOLAR ARRAY
MULTIPLE ACCESS
ANTENNAS
provides S–band

USER TERMINALS



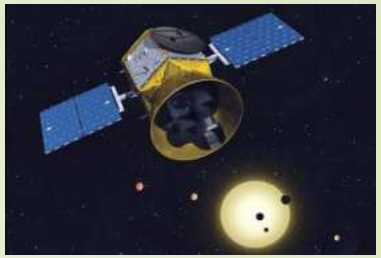
SATELLITE COMMAND CONTROL CENTRE

SATELLITE LIFE CYCLE



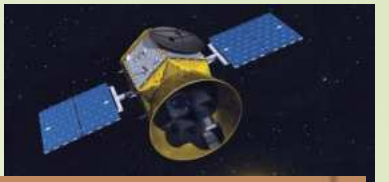
- SATELLITE LIFE IS ALWAYS MISSION SPECIFIC
- LAUNCH
- COMMISSIONING
- IN SERVICE
- END OF LIFE

SPACE & SATELLITE SYSTEMS



- SATELLITE
  - PAYLOAD
  - BUS
  - TELEMETRY, TRACKING & COMMAND (TT&C) SYSTEMS
  - COMMAND & DATA HANDLING (C&DH)
  - ATTITUDE DETERMINATION & CONTROL (ADCS)
  - DATA LINK FREQUENCY MANAGEMENT
- GROUND SEGMENT
  - GROUND STATIONS
  - TT&C SEGMENT
  - CENTERS TO MANAGE MISSION OPERATIONS & PAYLOAD
- USER SEGMENT

BANDS ORIGIN

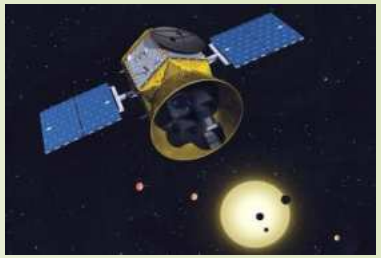


Band	Frequency Range	Origin of Name
I	up to 200 MHz	Unknown
G	200 to 250 MHz	Unknown
P	250 to 500 MHz	P for "previous", as the British used the band for the earliest radars, but later switched to higher frequencies.
L	0.5 to 1.5 GHz	L for "long" wave.
S	2 to 4 GHz	S for "short" wave. Don't confuse this with the short wave radio band, which is much lower in frequency
C	4 to 8 GHz	C for "compromise" between S and X band.
X	8 to 12 GHz	Used in WW II for fire control, X for cross (as in crosshair)
Ku	12 to 18 GHz	Ku for "kurz-under".
K	18 to 26 GHz	German "kurz" means short, yet another reference to short wavelength.
Ka	26 to 4-0	Ka for "kurz-above".
V	40 to 75 GHz	V for "very" high frequency band (not to be confused with VHF)
W	75 to 110 GHz	W follows V in the alphabet

SATELLITE FREQUENCY BANDS

Name	Band
VHF	30–300 MHz
UHF	300–1000 MHz
L	1–2 GHz
S	2–4 GHz
C	4–8 GHz
X	8–12 GHz
Ku	12–18 GHz
K	18–27 GHz
Ka	27–40 GHz
V	40–75 GHz
W	75–110 GHz

SPACE SEGMENT ARCHITECTURE



- SHAPE OF SPACE SEGMENT DEPENDS ON PURPOSE OF THE MISSION
  - MILITARY
  - CIVIL
  - SCIENTIFIC & EXPERIMENTAL RESEARCH
  - UNIVERSITY
- ORBITAL PLANES
- ORBITS
  - EQUATORIAL
  - POLAR
  - GEO STATIONARY

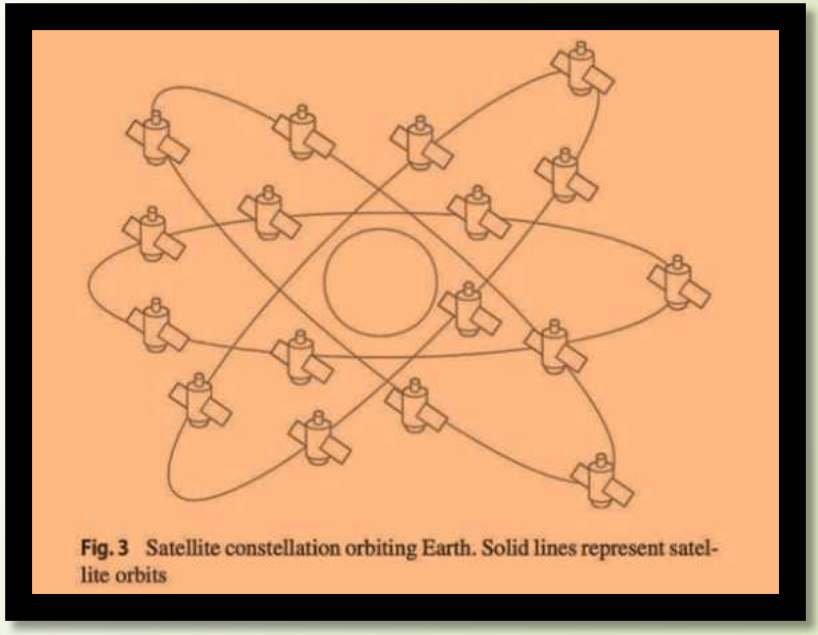
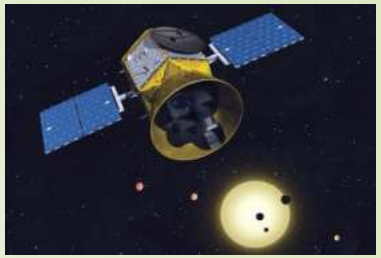
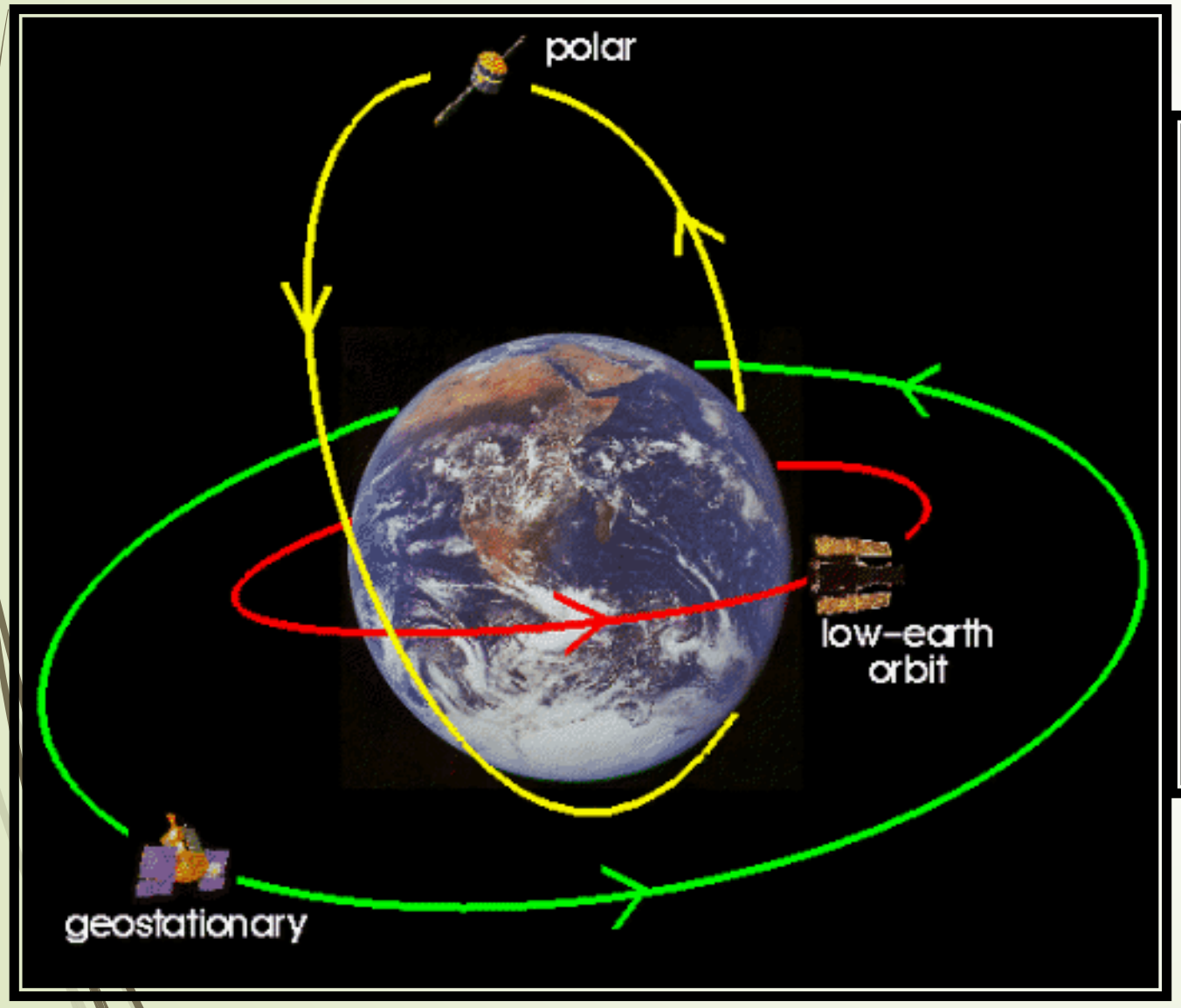
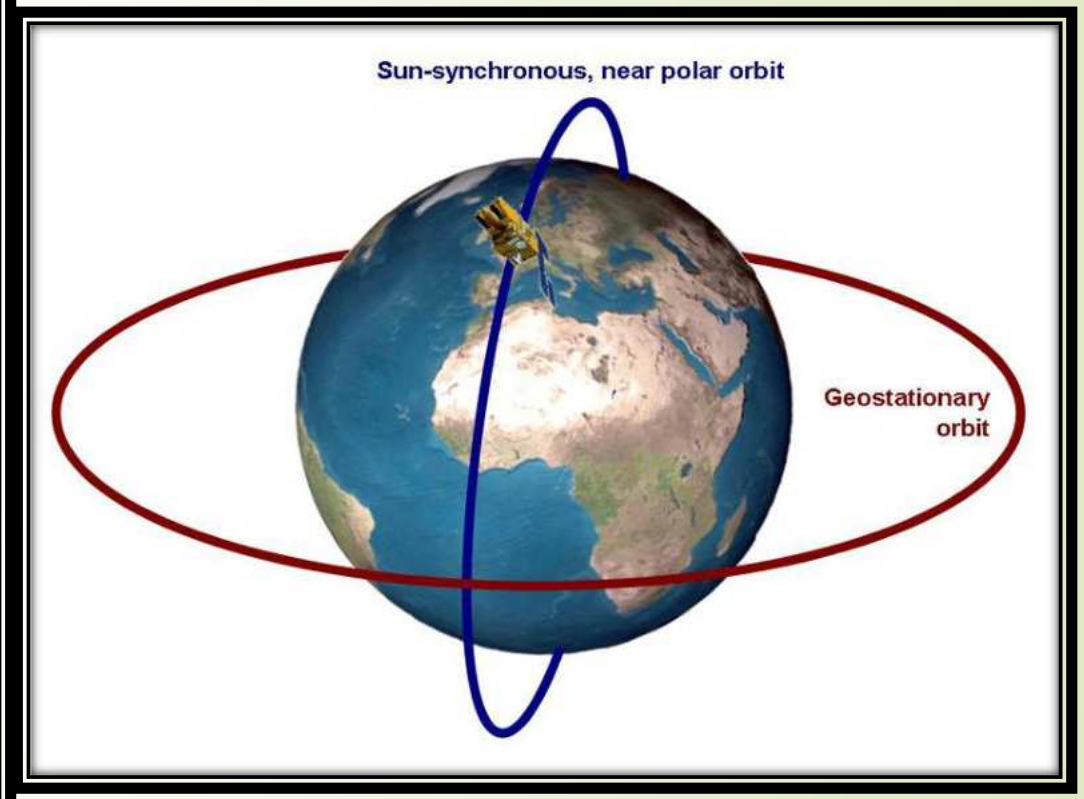


Fig. 3 Satellite constellation orbiting Earth. Solid lines represent satellite orbits

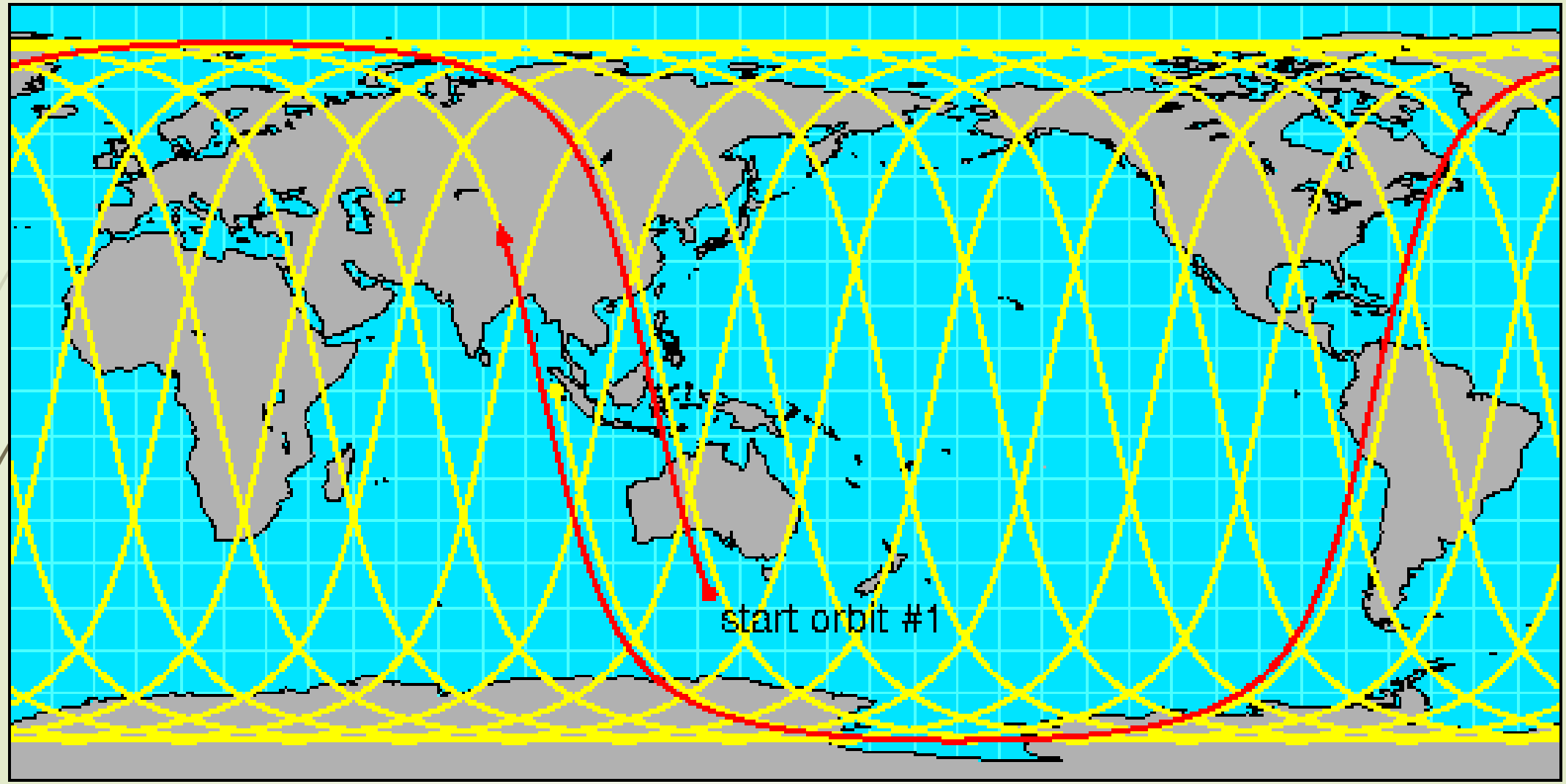
SATELLITE ORBITS



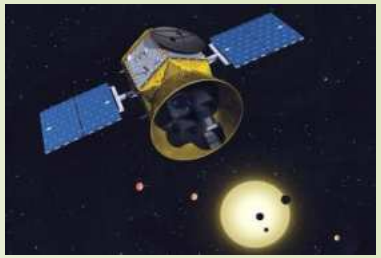




ORBIT DISPLAY IN A CONTROL STATION



SATELLITE CONSTELLATIONS

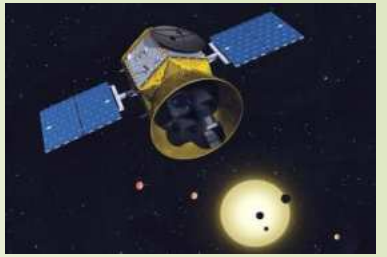


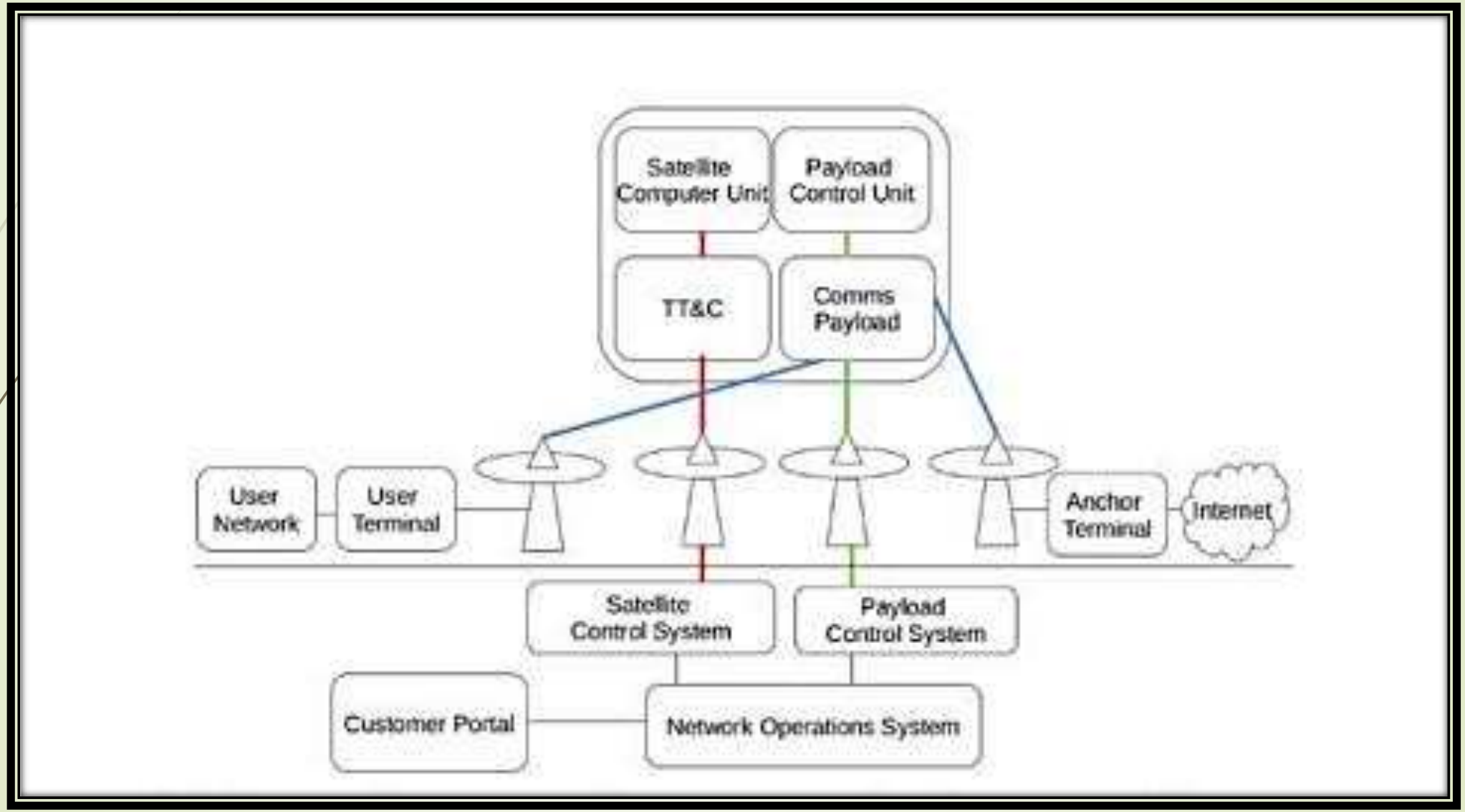
Company	Constellation Size	Satellite mass (kg)	Expected lifetime	Communication bands	Protocols
Planet	140	5	1–5 years	X-band S-band u UHF TT&C	DVB-S2 GSE IP
HawkEye 360	3 (present) 18 (future)	12.75	2–7 years	S-band X-band UHF TT&C S-band TT&C S-band ISL	Unknown
Starlink	12,000	227	5–7 years	Ka-band Ku-band V-band Optical ISL	Unknown
OneWeb	648	150	5 + years	Ka-band Ka-band V-band	Unknown
Leosat	108	1250	Unknown	Ka-band Optical ISL	DVB-S2 DVB-S2X

GROUND SEGMENT ARCHITECTURE

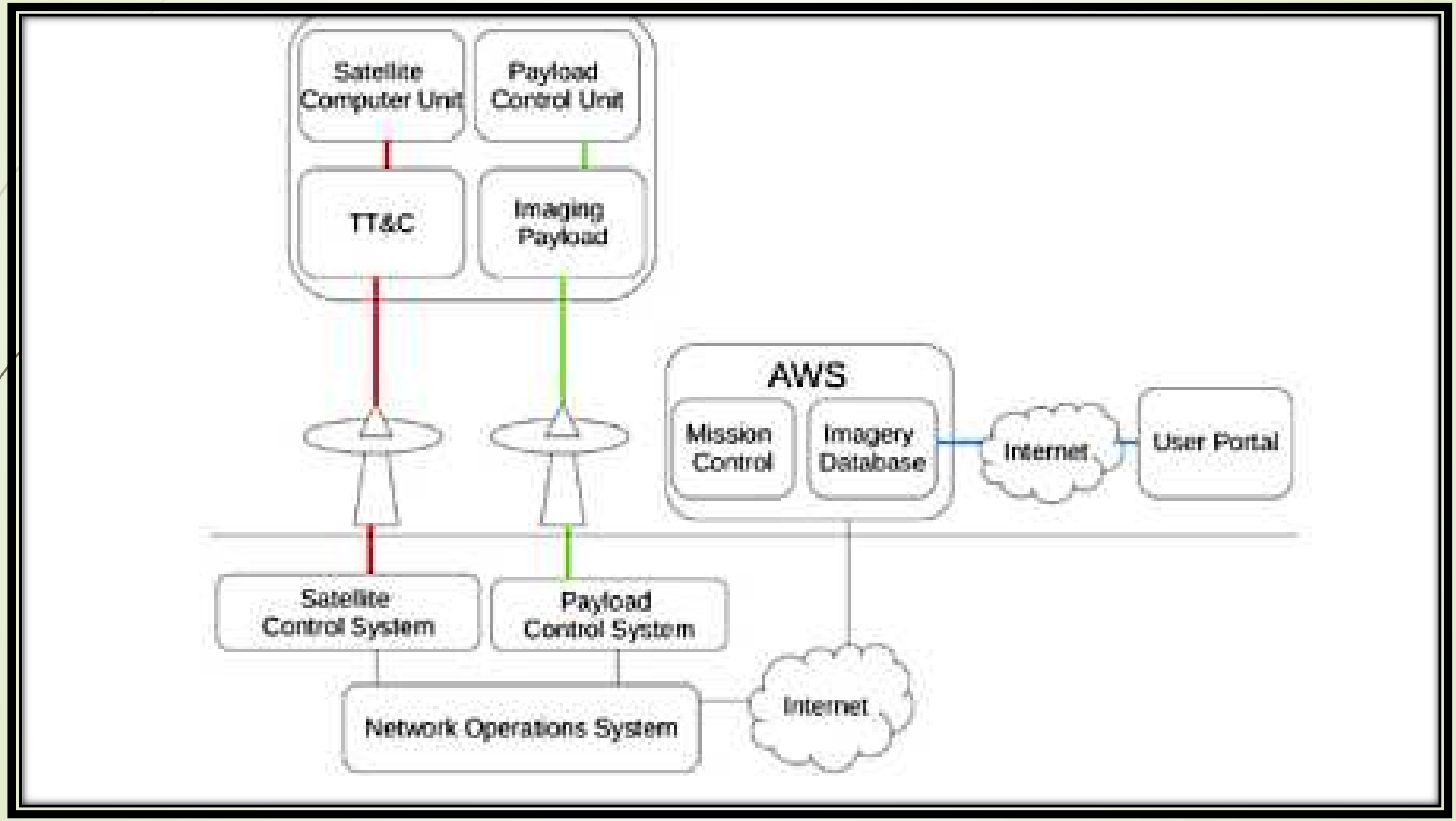
- ARCHITECTURE PURELY MILITARY SPECIFIC
- COMMUNICATION SATELLITES
- BROADCAST ONLY SATELLITES
- WEB BASED ACCESS

GROUND SEGMENT FOR COMMN SATELLITES

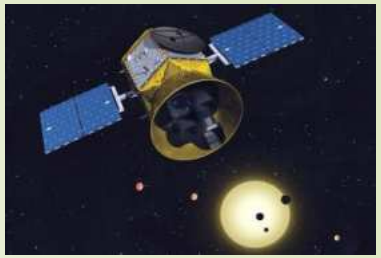




GROUND SEGMENT FOR WEB BASED ACCESS SATELLITES

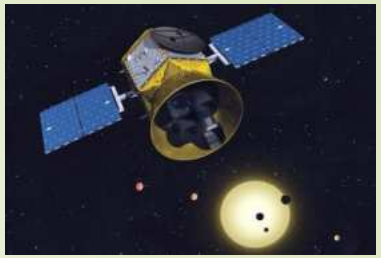


THREATS TO SPACE SYSTEMS

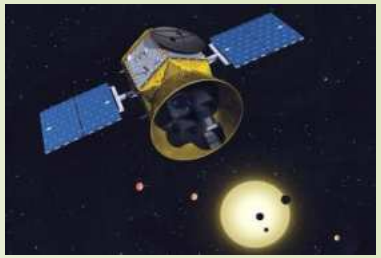


- CONSULTATIVE COMMITTEE FOR SPACE DATA SYSTEMS REPORT
  - SECURITY THREAT AGAINST SPACE MISSIONS
- GROUND SEGMENT
  - PHYSICAL ATTACKS
  - COMPUTER NETWORK EXPLOITATION(CNE)
  - CLOUD INFRASTRUCTURE
  - DATA CORRUPTION MODELS
  - SUPPLY CHAIN ATTACKS
  - UNPATCHED/OUTDATED/LEGACY COTS

COMMUNICATIONS



- TYPES OF ATTACK METHODOS
  - JAMMING
  - EAVESDROPPING
  - HIJACKING
  - SPOOFING OF LEGACY GPS
- IMPACT ON VARIOUS SYSTEMS BOTH SPACE & USER
- REGULATORY REQUIREMENTS



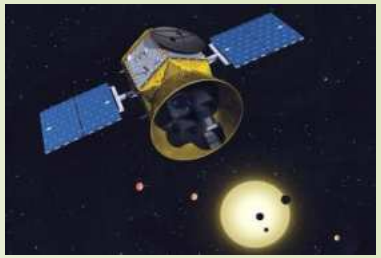
REVIEW & ANALYSIS OF SATELLITE INCIDENTS

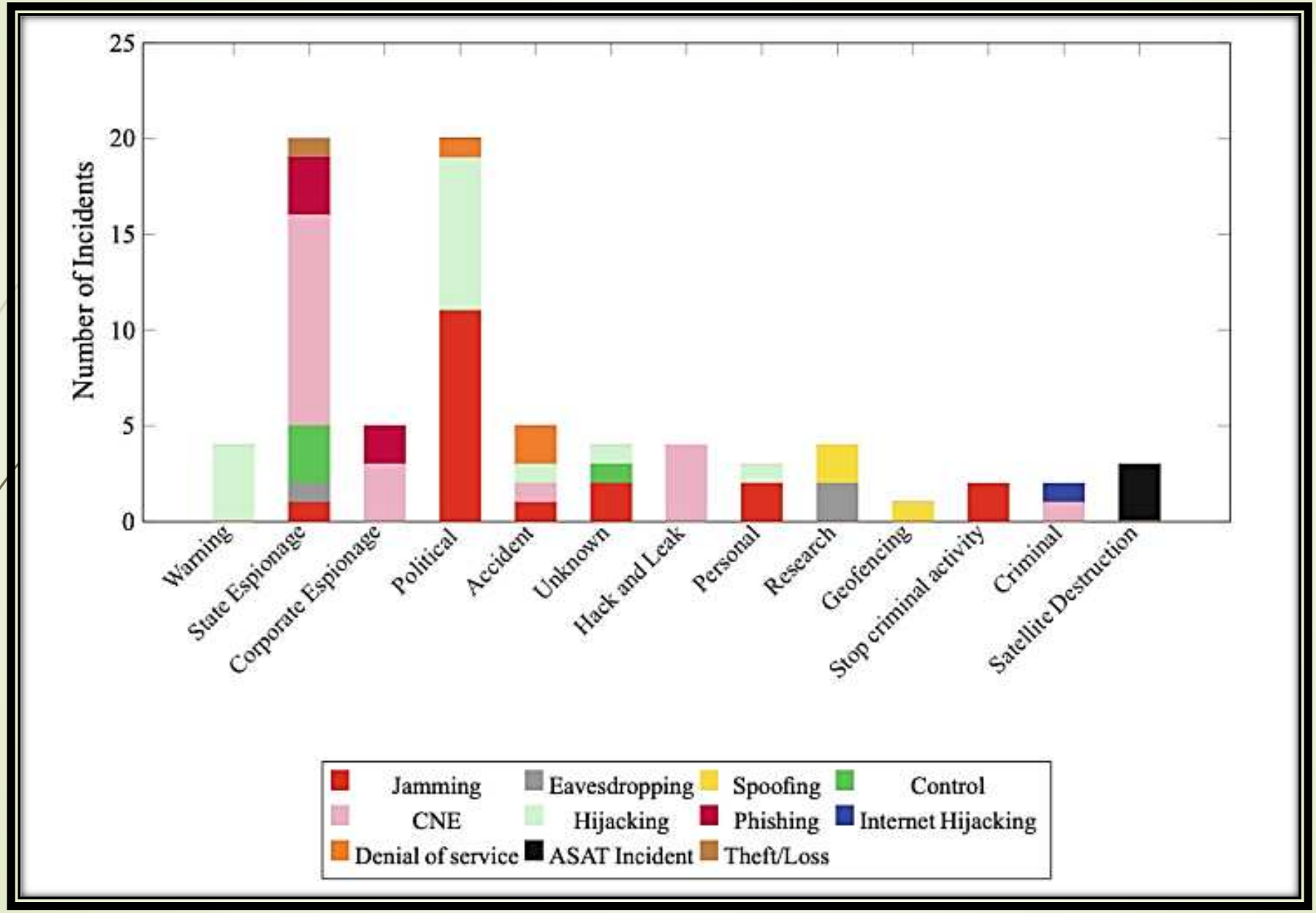
- CATEGORISATION
  - SEGMENT UNDER ATTACK OR EXPLOITED
  - TYPE OF TARGET
    - GOVT, COMMERCIAL, CIVILIAN, MILITARY
  - TYPE OF INCIDENT
    - JAMMING, SPOOFING, CNE, HIJACKING, etc
  - MOTIVATION FOR THE INCIDENT
    - STATE ESPIONAGE, HACK & LEAK, CRIMINAL ACTIVITY , ETC

SEGMENT & SECTOR ANALYSIS OF SATELLITE SECURITY INCIDENTS

	Category	Frequency
Segment	Ground	83
	Space	8
	Data communications	38
	Unknown	2
Sector	Government	91
	Commercial	28
	Civilian	11
	Military	11
Incident type	Jamming	19
	Eavesdropping	3
	Spoofing	3
	Control	4
	CNE	30
	Hijacking	16
	Phishing	3
	Internet hijacking	1
	Denial of service	3
	Theft/loss	48
	ASAT incident	3

MOTIVATION OR INTENT

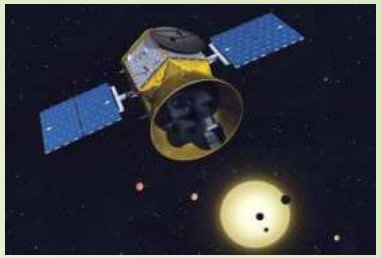


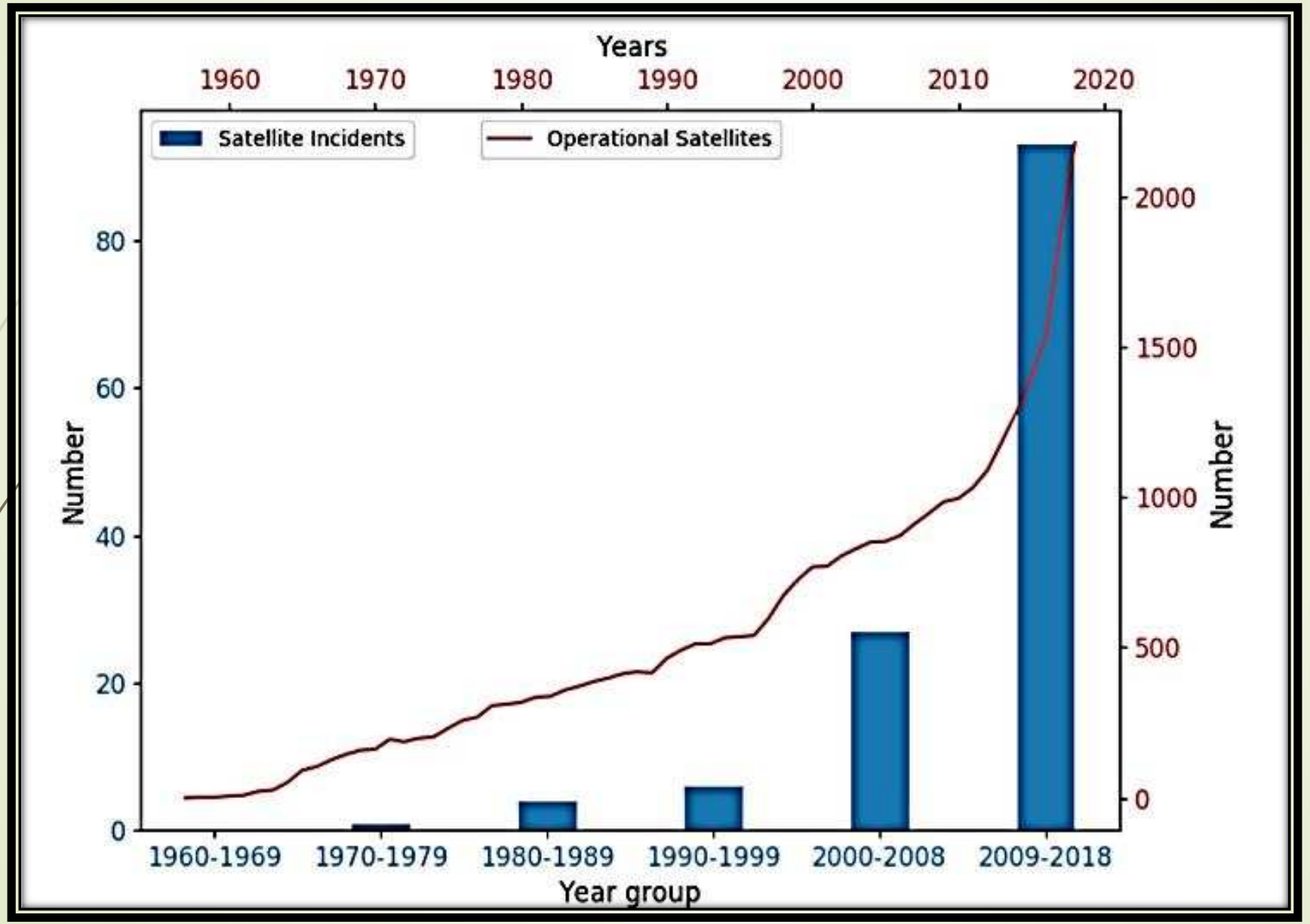


SMALL SATELLITE CLASSIFICATIONS

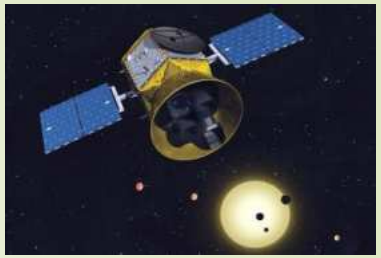
Classification	Mass (kg)
Minisatellite	100–500
Microsatellite	10–100
Nanosatellite	1–10
Picosatellite	0.1–1
Femtosatellite	0.01–0.1

SATELLITE ATTACKS PER GROUP





KEY ENABLING TECHNOLOGIES IN NEW SPACE



- CUBE SATS
- COTS COMPONENTS, OPEN SOURCE & GPS LICENSED PRODUCTS
- ACADEMIC INSTITUTIONS
  - COTS COMPONENTS
  - FILED PROGRAMMABLE GATE ARRAYS
  - SYSTEM ON CHIP COMPONENTS
  - MICRO CONTROLLERS
  - OPEN SOURCE SOFTWARE
    - KubOS10, UP Sat, EQUiSat

KEY ENABLING TECHNOLOGIES IN NEW SPACE

- SOFTWARE DEFINED RADIOS (SDRs)
  - REPRESENT A RADIO THAT HAS SOFTWARE CONTROL OVER SOME FUNCTIONS, AND STILL BEING IMPLEMENTED IN ANALOG ELECTRONICS
  - SDRs AFFORD FLEXIBILITY & RECONFIGURABILITY
  - REMOVE THE NEED FOR DEDICATED HARDWARE TO SAVE SAPCE ON SATELLITE BUSES
  - COMMON SDRs – RTL-SDR, USRP AND LINE SDR

SDR SHOWS A MAJOR SHIFT FROM OLD SPACE TO NEW SPACE

OPEN SYSTEMS INTERCONNECTION(OSI) MODEL

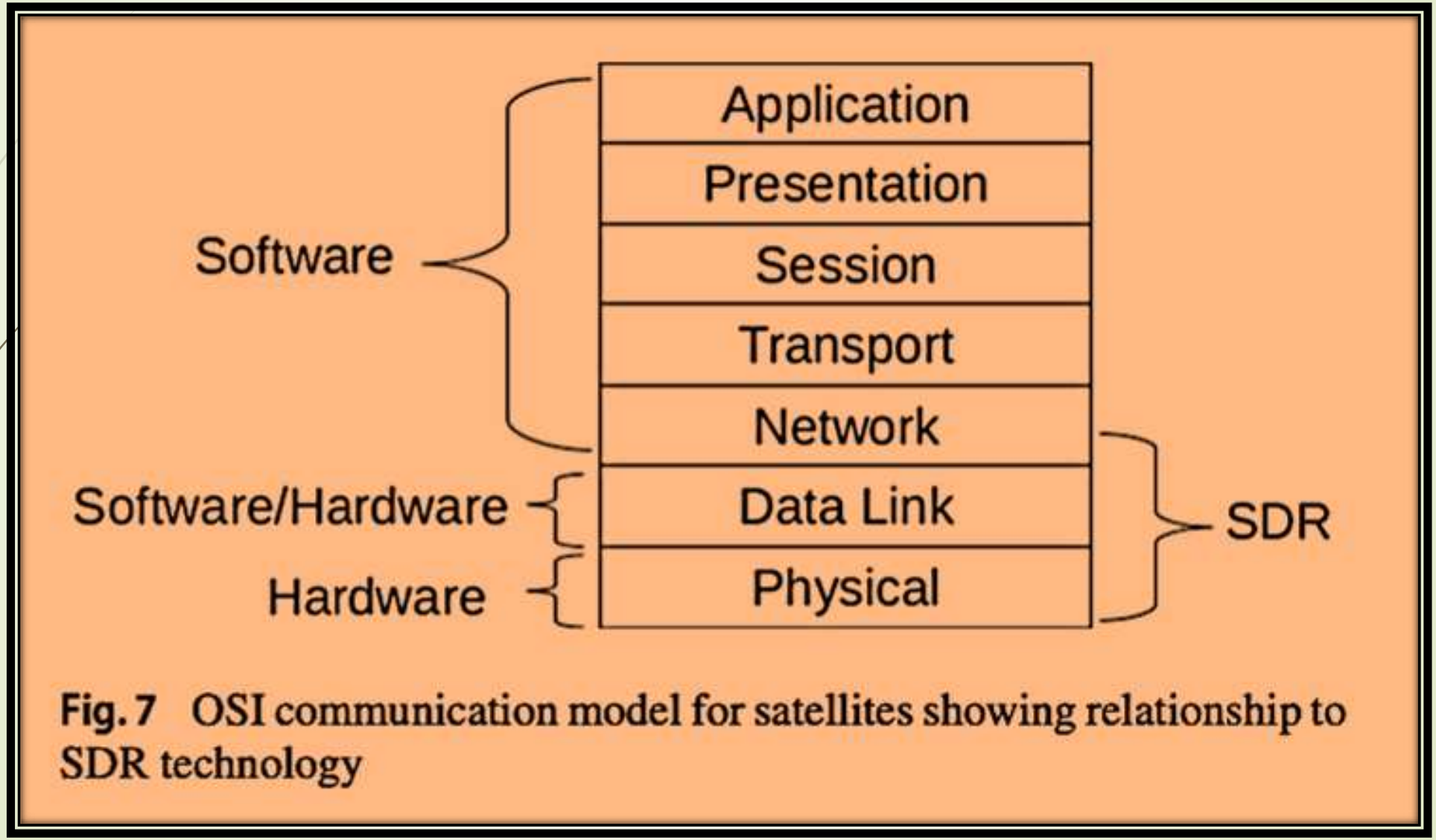
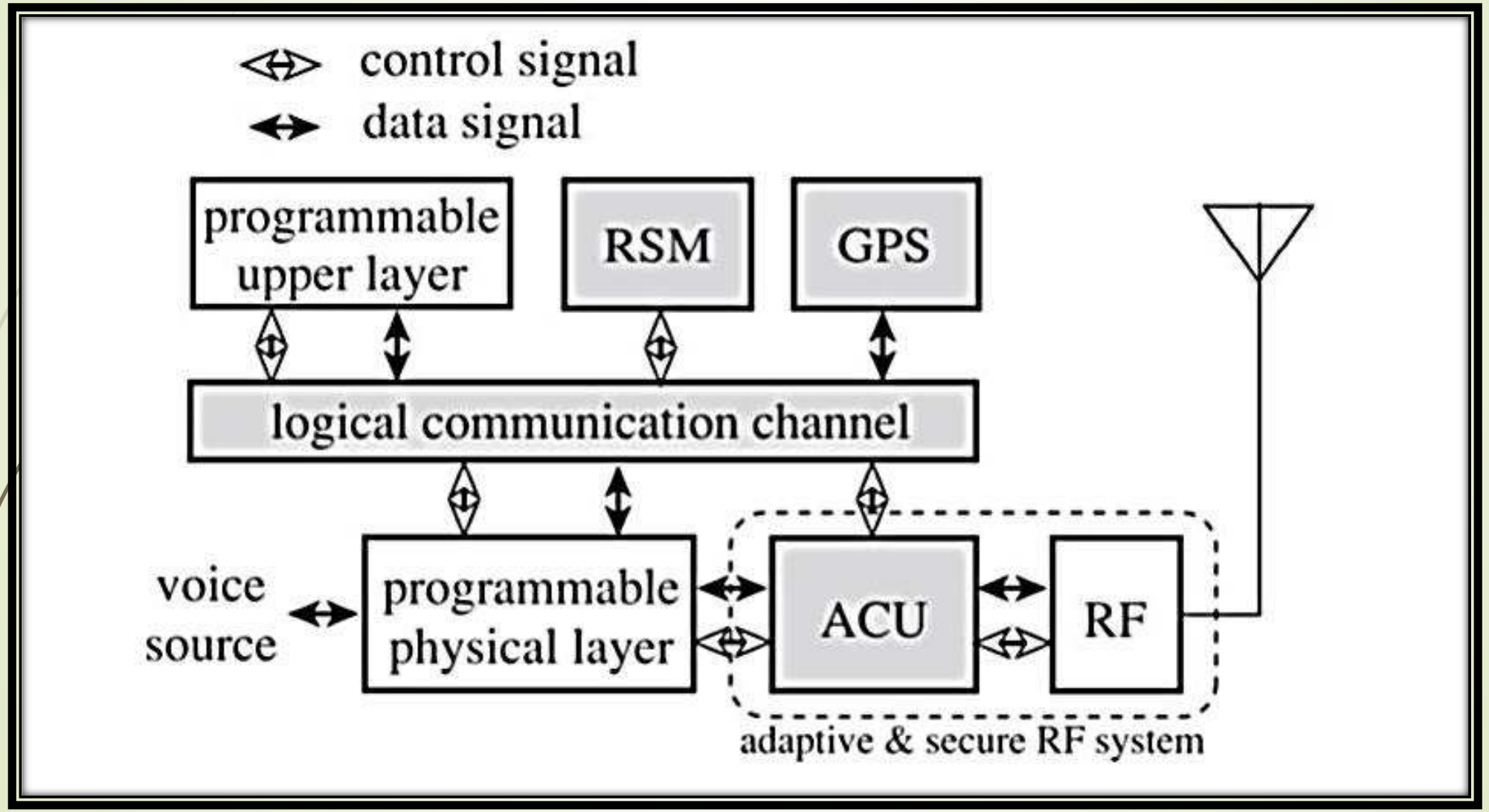
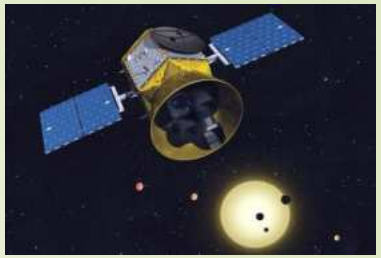


Fig. 7 OSI communication model for satellites showing relationship to SDR technology

ACU - RSM BASED SDR HARDWARE ARCHITECTURE

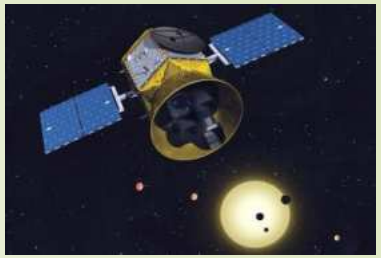


GROUND SEGMENT



- AUTOMATION & AUTONOMY
- ABILITY OF GROUND STATION & MISSION CONTROL CENTRE TO COMMAND, CONTROL AND RECEIVE PAYLOAD TRANSMISSIONS FOR SATELLITES WITHOUT HUMAN INTERVENTION IS THE DESIRABLE ONE
- EXPERIMENTATION IS A CONTINUOUS PROCESS
- COMMERCIAL INTERESTS
- CLOUD COMPUTING
- EDGE COMPUTING

SPACE PROTOCOLS & SECURITY



- SATELLITE COMMUNICATION LINKS SUFFER FROM HIGHER ERROR RATES & LATENCIES THAN TERRESTRIAL CABLED NETWORKS
- CONSULTATIVE COMMITTEE FOR SPACE DEFENCE SYSTEMS (CCSDS) HAS CREATED A SET OF PROTOCOLS FOR TELEMETRY, TELE COMMAND AND OSI MODEL LAYERS
- CCSDS IS RESPONSIBLE FOR MAKING DATA COMMUNICATION MORE ACCESSIBLE TO NEW ENTERPRISES

SECURITY PROTOCOLS

- PHYSICAL
- OPTICAL COMMUNICATION PAYLOADS USING VISIBLE LIGHT COMMUNICATIONS(VLCs)

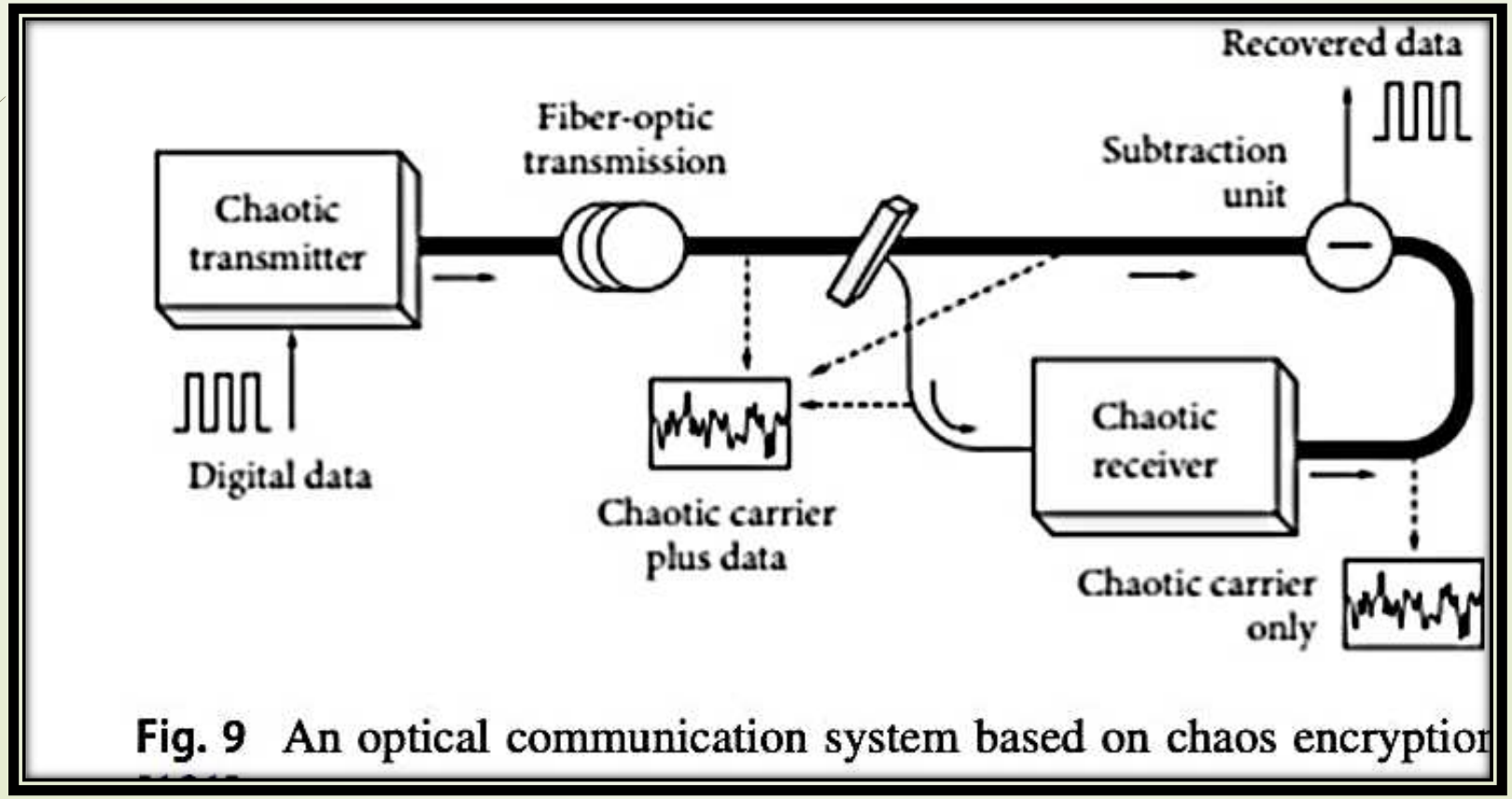
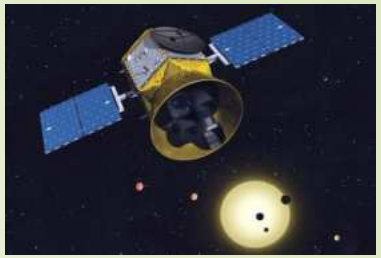


Fig. 9 An optical communication system based on chaos encryption

SECURITY PROTOCOLS

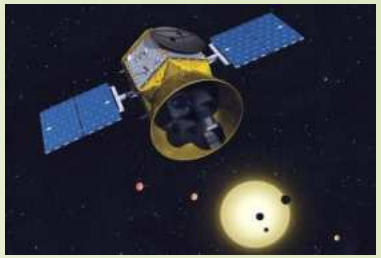


- DATA LINK
  - EDUCATIONAL INSTITUTIONS EMPLOY SIMPLE DATA LINK
- CCSDS SAPCE DATA LINK SECURITY (SDLS) PROTOCOL EXTENDS ITS DATA LINK PROTOCOLS TO INCORPORATE
  - ENCRYPTION OF FRAME DATA
  - AUTHENTICATION
  - INTEGRITY
  - SECURITY PROTOCOLS ARE TO BE IN ADHERENCE TO ISO 7498-2
- NETWORKING & TRANSPORT
  - SPACE PACKET PROTOCOL(SSP) & DELAY TOLERANT NETWORK BUNDLE PROTOCOL (DTN BP)
  - BROAD BAND SERVICES USE IP PROTOCOLS
  - REALIABILITY SERVICES EMERGE THROUGH TRANSPORT PROTOCOLS

SECURITY PROTOCOLS

- IP SEC
- CUBE SPACE PROTOCOL
- APPLICATION LAYER PROTOCOLS
- **USER SEGMENT**
- APPLICATION OF SATELLITE SYSTEMS
- NAVIGATION
  - GNSS RECEIVER FORM CONSTELLATION TO DETERMINE LOCATION
- TV
  - DISH & SET TOP BOX
- COMMUNICATION WITH DEDICATED HARDWARE
- INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT(ISCCP) WEBSITE

CRYPTOLOGY FRO NEW SPACE

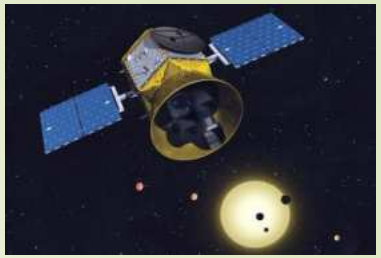


- NAVIGATION MESSAGE AUTHENTICATION MECHANISM
- CHIPS MESSAGE ROBUST AUTHENTICATION(CHIMERA) IS HYBRID NMA SPREADING CODE AUTHENTICATION FOR GPS SIGNALS
- OPTICAL COMMUNICATION PROTOCOLS
  - HIGH QUALITY OPTICAL LINKS
  - SATELLITE –QKD CAN ACHIEVE ULTRA LONG DISTANCE QUANTUM COMMUNICATION IN A 1000 KM RANGE
  - SATELLITE TERMINALS IN SPACE FOR QUNATUM COMMUNCIATION

OPEN CHALLENGES

- LIGHT WEIGHT AUTHENTICATION & SECURE COMMUNICATION
  - SATELLITE COMMN PROTOCOLS
  - SECURITY CONTROLS
  - MISSION DEPENDENT PROTOCOLS
  - PHYSICAL LAYER SECURITY

SECURITY KEY MANAGEMENT

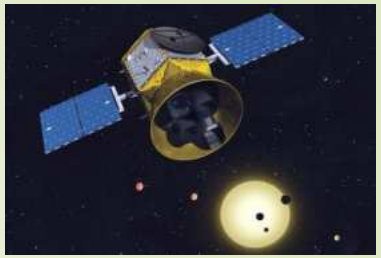


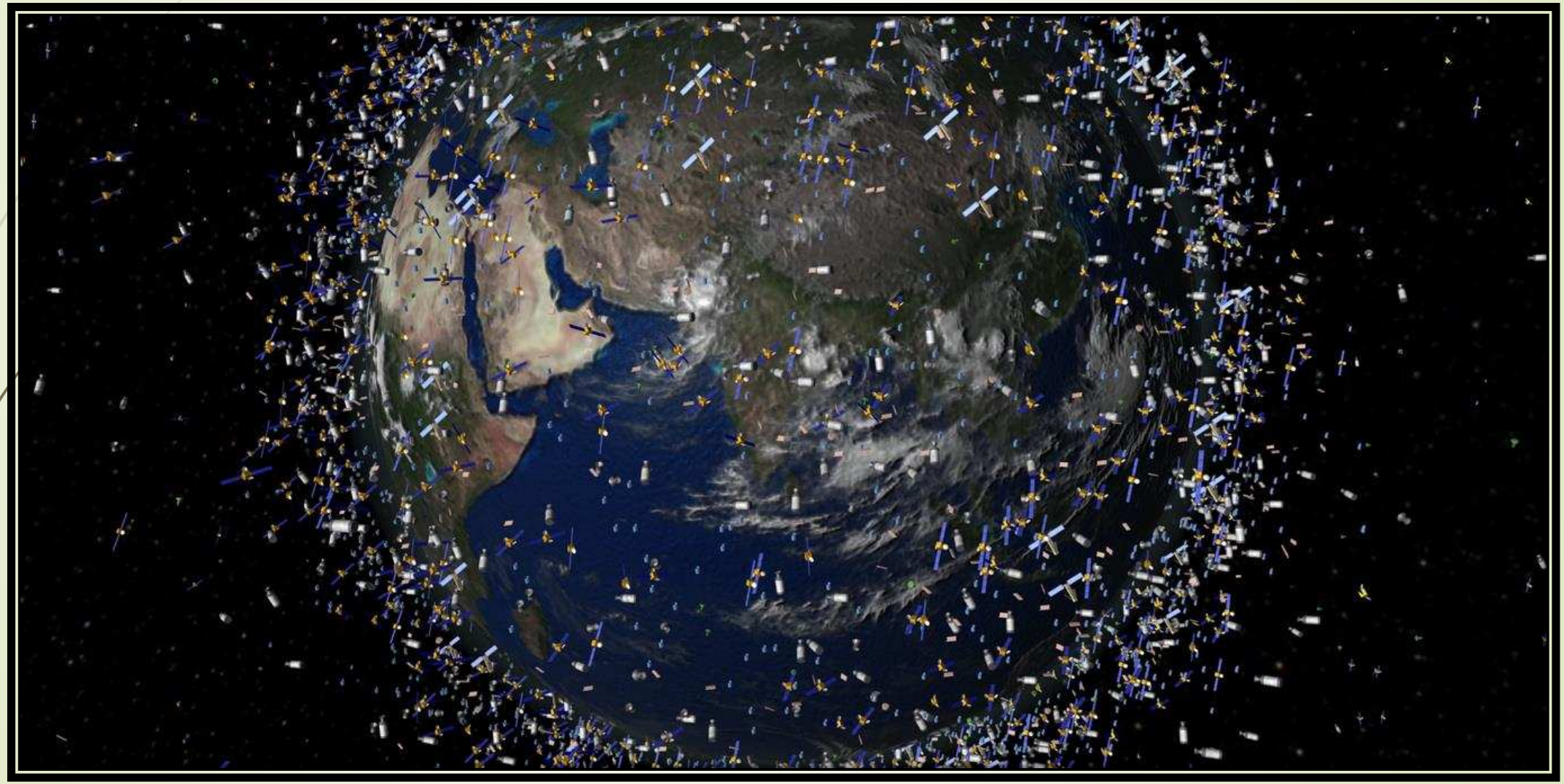
- SCALABILITY
- GROUP DYNAMICS
- KEY PROTECTION
- QUANTUM KEY DISTRIBUTION
- SOFTWARE/FIRMWARE UPDATES
- RELIABLE SOFTWARE
- SECURE POSITIONING OF SATELLITES
- ROUTING IN ISLs
- DISTRIBUTED CONTROL
- FAULT TOLERANCE

SECURITY KEY MANAGEMENT

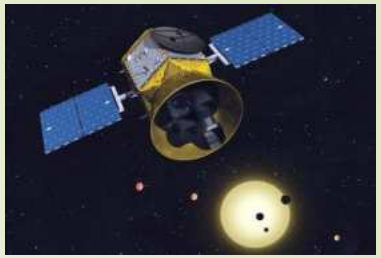
- INTELLIGENCE GATHERING
  - FREQUENCY REGISTRATION WITH INTERNATIONAL TELECOMMUNICATION UNION (ITU), UNO
  - GROUND SEGMENT ATTACKS
  - NEW PLAYERS
  - SIGNAL MANIPULATION
  - INTRUSION DETECTION & PREVENTION
  - USER SEGMENT INTERFACE

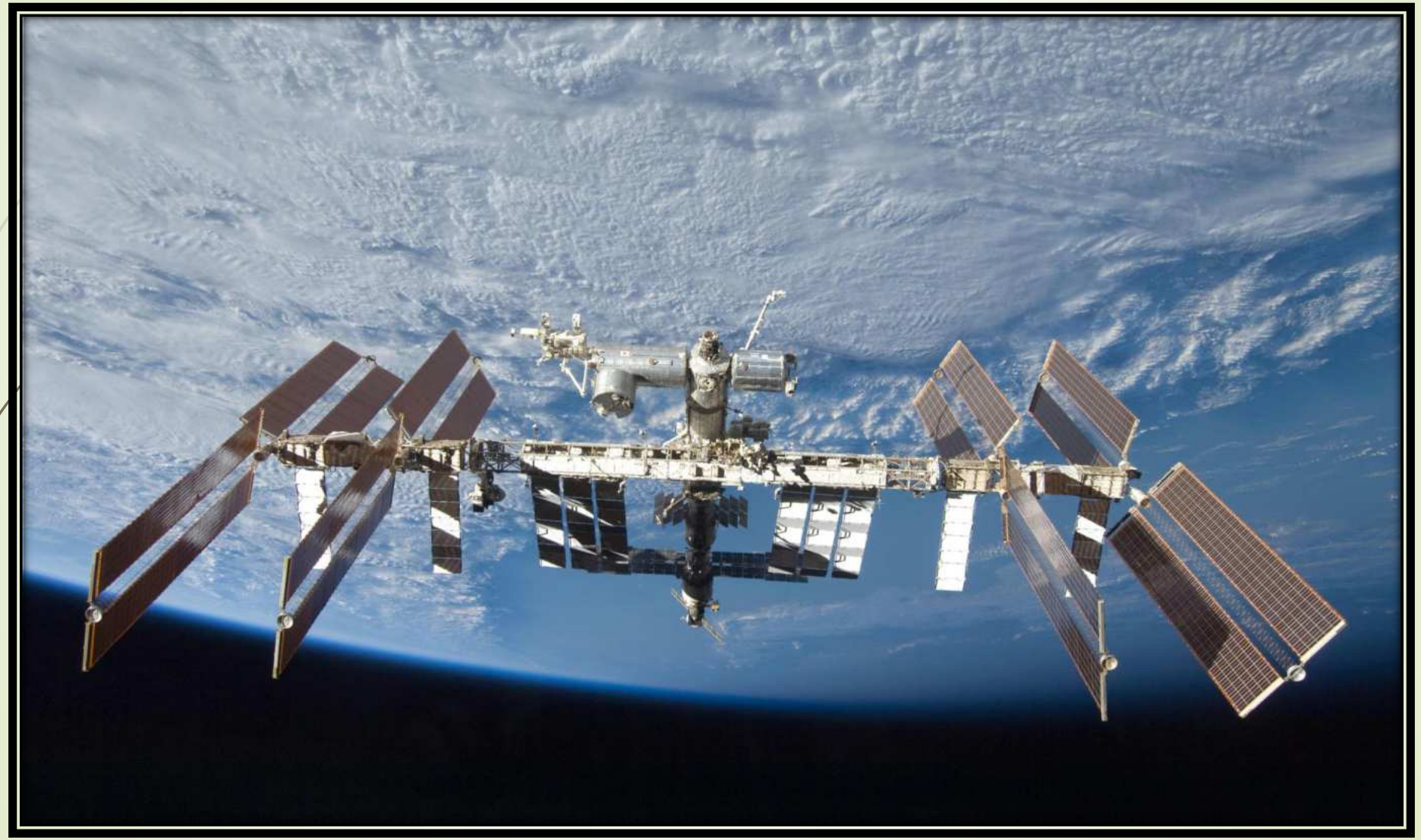
SPACE DEBRIS

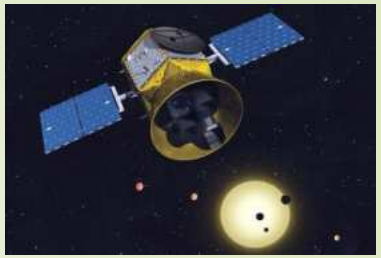




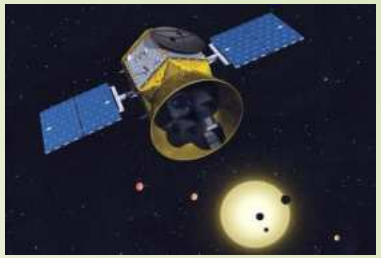
INTERNATIONAL SPACE STATION







CONCLUSION



JAI HIND