

Table of Contents

Foreword and Acknowledgements	1
1 Earth Observation History on Technology Introduction	7
1.1 GEOSS (Global Earth Observation System of Systems):	16
1.2 Decadal Survey:	19
1.3 Some background on policies of commercial high-resolution imagery	21
1.4 Sensor/Technology Development	24
1.4.1 Concepts in Optical Observations	26
1.4.1.1 Solid-state (digital) imaging – CCD detector technology	29
1.4.1.2 Solid-state (digital) imaging – CMOS/APS detector technology	42
1.4.1.3 Solid-state (digital) imaging – STJ detector technology	49
1.4.1.4 Introduction of airborne digital frame cameras (photogrammetry)	50
1.4.1.5 Advanced CCD technology in astronomy missions	57
1.4.1.6 Stereoscopic imaging in the optical region	59
1.4.2 Spectrometry, imaging spectrometry, and hyperspectral imaging	63
1.4.2.1 Imaging spectrometry	64
1.4.2.2 Spectral dispersion methods	70
1.4.2.3 ETF (Electronically Tunable Filter) systems and technologies	71
1.4.2.4 Acousto-Optic Tunable Filters (AOTF)	72
1.4.2.5 LCTF (Liquid Crystal Tunable Filter)	74
1.4.2.6 FPI (Fabry-Perot Interferometer) tunable filter	75
1.4.3 Microwave Region, Active Observations (Radars)	77
1.4.3.1 SAR (Synthetic Aperture Radar) concepts	79
1.4.3.2 Radar (microwave) instrument classes in Earth observation	92
1.4.3.3 Electronic beam steering	94
1.4.3.4 SAR interferometry (InSAR techniques in the microwave region)	97
1.4.3.5 Scatterometry – the microwave measurement of wind fields	101
1.4.3.6 Bistatic and Multistatic Systems in Remote Sensing	110
1.4.3.7 SAR imaging and detection of moving targets (motion sensing)	116
1.4.3.8 Digital Beam Forming (DBF)	121
1.4.3.9 SAR technology roadmap	125
1.4.4 Microwave Region, Passive Observations	140
1.4.4.1 Microwave radiometers	141
1.4.4.2 Soil moisture in passive microwave radiometry	145
1.4.4.3 Viewing geometries of microwave radiometers in LEO missions	149
1.4.4.4 Pushbroom versus synthetic aperture concept in radiometry	152
1.4.4.5 Microwave sounding from GEO (Geostationary Earth Orbit) satellites	154
1.4.5 Optical Region, Active Observations (LIDARs)	160
1.4.6 Sounding of the Atmosphere	164
1.4.6.1 Monitoring of ozone in the atmosphere	173
1.4.6.2 Occultation measurements	175
1.4.7 Sounding of the Ionosphere	177
1.4.8 Some Instrument/Observation Techniques	184
1.4.8.1 QWIP (Quantum-Well Infrared Photodetector)	185
1.4.8.2 TDI (Time Delay Integration)	188
1.4.8.3 Polarimetric radiometry, imaging polarimeters, SAR polarimeters	188
1.4.8.4 FTS (Fourier Transform Spectrometer) instruments	190
1.4.8.5 Onboard radiometric sensor calibration	194
1.4.8.6 Lightning detection instruments (event-based monitoring)	197
1.4.8.7 Some telescopes for optical instruments	199
1.4.8.8 Adaptive optics (AO)	201
1.4.8.9 Optical phased array (OPA) technology	205
1.4.8.10 Advanced telescope design – lightweighted optics and structures	207

1.4.8.11	Deployable space structures	213
1.4.8.12	Inflatable Space Structures	213
1.4.8.13	MEMS (Micro–Electro–Mechanical System) technology	218
1.4.8.14	Cryogenic cooling techniques of observation instruments	220
1.4.8.15	Uncooled infrared detectors and HTS (High–Temperature Superconductivity)	228
1.4.8.16	Observations in the FIR (Far Infrared) region, FIR detectors	230
1.4.8.17	Vegetation fluorescence in passive remote sensing	234
1.4.8.18	Sparse aperture imaging concepts	236
1.4.8.19	Astronaut–acquired photography	239
1.5	Fundamental Science Limits in Space Flight and Earth Observation	241
1.6	Spacecraft Systems	248
1.6.1	Spacecraft platform stabilization concepts	248
1.6.2	Spacecraft/Component Design Topics	251
	Spacecraft buses:	253
1.6.2.1	Introduction of COTS parts in spacecraft	258
1.6.2.2	Satellite structure vibration/jitter damping	260
1.6.3	Spacecraft power generation – solar cells, batteries, etc.	263
1.6.3.1	Electric power subsystem (EPS) on spacecraft	272
1.6.3.2	Fuel cell power systems on spacecraft	275
1.6.3.3	RTG (Radioisotope Thermoelectric Generator)	277
1.6.3.4	NPS (Nuclear Power System) in Soviet/Russian space program	281
1.6.4	SPS (Solar Power Satellites): PowerSats	283
1.6.5	Spacecraft Avionics and Onboard Data Handling (bus systems)	289
1.6.5.1	MIL–STD–1553B	291
1.6.5.2	OBDH (On–Board Data Handling)	293
1.6.5.3	CAN (Controller Area Network)	294
1.6.5.4	I2C (Inter–IC or Inter–Integrated Circuit)	295
1.6.5.5	FireWire / IEEE 1394	296
1.6.5.6	X2000 bus	297
1.6.5.7	SpaceWire	298
1.6.5.8	SpaceLAN (Spacecraft Local Area Network)	306
1.6.5.9	Wireless interfacing on spacecraft (proximity networks)	307
1.6.5.10	Plug–and–play systems	310
1.6.6	Onboard data compression techniques	313
1.6.6.1	Onboard SAR data compression	316
1.6.7	Spacecraft communications	318
1.6.7.1	Spacecraft RF (Radiofrequency) communications	319
1.6.7.2	Introduction of CCSDS protocols	326
1.6.7.3	FSO (Free–Space Optics) communications with satellites	329
1.6.7.4	Internet access for future spacecraft LAN services	333
1.6.7.5	DTN (Delay/Disruption Tolerant Networking)	341
1.6.7.6	Relay satellites	343
1.6.7.7	DAB (Digital Audio Broadcasting)	345
1.6.7.8	AIS (Automated Identification System) – spaceborne maritime traffic monitoring	347
1.6.8	Spacecraft Operations	350
1.6.8.1	Introduction of computers in spaceflight	350
1.6.8.2	Onboard operating systems	355
1.6.8.3	Satellite onboard autonomy	360
1.6.8.4	Autonomous ground stations and systems	367
1.6.8.5	Spaceborne data collection systems (DCS)	368
1.6.8.6	Hibernation modes in spacecraft operations	369
1.6.8.7	Special S/C maneuvers and/or rescue/repair operations	371
1.6.9	Cooperative Distributed Space Systems – Satellite Formations	377
1.6.9.1	Survey of early formation–flying (EO) demonstrations	383
1.6.9.2	Intersatellite communication and navigation	387
1.6.9.3	Operational architecture concepts of DSS networks	391
1.6.10	Space Environment Experiments	392

1.6.11 Orbital debris	396
1.6.11.1 Debris policies and spacecraft removal from orbit at end-of-life	400
1.6.12 Some comments on launch deployment capabilities	404
1.7 On-orbit Propulsion	405
1.7.1 On-orbit solar electric propulsion (SEP or simply EP) systems	405
1.7.1.1 Types of electric propulsion systems	406
1.7.1.2 Introduction of HET technology	410
1.7.1.3 Examples of electrothermal propulsion systems (arcjets, resistojets)	412
1.7.1.4 Background on ion propulsion history:	414
1.7.1.5 Electric propulsion on commercial satellites	420
1.7.2 Solar sails	421
1.7.3 Tether Experiments	426
1.8 ISS (International Space Station) Build-up Phase	429
1.9 Small satellites in spaceflight/remote sensing	449
1.9.1 Small satellite classification	453
1.9.2 UoSat family of small satellites:	455
1.9.3 Small satellite technology transfer programs – opening the era of global participation in space missions	458
1.9.4 Small satellite initiatives in the USA	462
1.9.5 Small satellite development in the rest of the world:	467
1.9.6 University/Student-Developed Satellites & Payloads	473
1.9.6.1 CubeSats	476
1.9.7 Current status and outlook in the smallsat service spectrum	478
1.10 Overview of Operational Meteorological Missions	482
1.10.1 Contributions of Environmental Satellite Data to Meteorology	485
1.10.2 LEO (Low Earth Orbit) Meteorological Satellite Missions	489
1.10.2.1 Sea Surface Temperature (SST) measurements from LEO satellites	493
1.10.3 GEO (Geostationary Orbit) Weather Satellites	496
1.10.3.1 Sea Surface Temperature (SST) from GEO satellites	500
1.10.4 GPS/GNSS meteorology – RF (Radio Frequency) occultation monitoring ..	502
1.10.5 GPS/GNSS meteorology – ground-based networks	505
1.10.6 GPS/GNSS bistatic ocean reflection measurements	507
1.11 Oceanography – A growing demand in Earth Observation	512
1.11.1 Physical oceanography	514
1.11.2 Satellite Altimetry	517
1.11.2.1 Altimetry principles	523
1.11.2.2 Geodetic altimetry	524
1.11.2.3 Delay-Doppler altimeter concept	525
1.11.3 SST (Sea Surface Temperature)	526
1.11.4 Ocean color observations	526
1.11.5 SSS (Sea Surface Salinity)	528
1.11.6 Oversight of ocean programs by global organizations	529
1.12 Solar-Terrestrial Connection	530
1.12.1 Solar radiation and Earth's atmosphere	531
1.12.2 Earth's Radiation Budget and Solar Constant	534
1.12.3 Solar Wind Observation	542
1.12.4 Earth's Magnetosphere	550
1.12.5 Space Weather	555
1.12.6 X-ray imaging	558
1.13 Navigation – Geodesy in Action	570
1.13.1 Some background on datums and reference systems	572
1.13.1.1 Geodetic reference frames	575

1.13.1.2 Gravity datums and some measurement concepts	583
1.13.2 Attitude sensing and actuation instruments	588
1.13.2.1 Sun sensors	591
1.13.2.2 Sextant–type attitude and position determination in spaceborne missions	593
1.13.2.3 Gyroscopes	595
1.13.2.4 Magnetometry and magnetometers	598
1.13.2.5 Star sensors	601
1.13.2.6 Advanced actuators –CMG (Control Moment Gyroscope)	607
1.13.2.7 Spacecraft/platform and instrument pointing	614
1.13.3 Tracking Techniques	618
1.13.3.1 Doppler tracking techniques	619
1.13.3.2 Satellite–to–satellite tracking technique (SST)	622
1.13.3.3 VLBI (Very Long Baseline Interferometry) and SVLBI (Space VLBI)	623
1.13.3.4 Nulling interferometry	626
1.13.3.5 Satellite Laser Ranging (SLR)	628
1.13.3.6 Active laser tracking systems	631
1.13.3.7 Gradiometry, accelerometry, drag–free satellites	632
1.13.3.8 Precise Orbit Determination (POD)	640
1.13.3.9 Gravitomagnetism, frame dragging and gravitational lensing	644
1.13.4 Introduction of quantum technology applications in spaceflight	648
1.14 Satellite Orbits	653
1.14.1 LEO (Low Earth Orbit)	654
1.14.1.1 Sun–Synchronous Orbit (SSO), a LEO subgroup	658
1.14.1.2 Exact repeat orbits (a LEO subgroup)	661
1.14.2 GEO (Geostationary Earth Orbit)	664
1.14.2.1 GSO (Geosynchronous Orbit)	668
1.14.2.2 GTO (Geosynchronous Transfer Orbit)	670
1.14.3 MEO (Medium Earth Orbit)	672
1.14.4 HEO (Highly–elliptical Earth Orbit)	673
1.14.4.1 Molniya–type orbits (a HEO subgroup)	674
1.14.5 Halo orbits (orbits around the Sun/Earth Lagrangian Points, L1 or L2)	677
1.14.6 Observation coverage of constellations	683
1.15 Orbital maneuvering and encounters	685
1.16 On–Orbit Servicing (OOS) missions	688
1.17 Satellite Radionavigation Systems	702
1.17.1 LORAN (Long–Range Navigation) and other pre–GPS systems	702
1.17.2 The Transit System	704
1.17.3 NAVSTAR/GPS (Global Positioning System)	706
1.17.4 GLONASS (Global Orbiting and Navigation Satellite System)	708
1.17.5 GPS and GLONASS, applications in space	709
1.17.6 GNSS (Global Navigation Satellite System) Augmentation Systems	725
1.17.7 Galileo	730
Agreements on GPS and Galileo navigation signal standards:	731
1.17.8 CNSS (Compass/BeiDou Navigation Satellite System)	732
1.17.9 QZSS (Quasi–Zenith Satellite System)	734
1.18 Services	735
1.19 Start of International Cooperation	741
1.19.1 Realization of international cooperation in manned space programs	749
1.20 A brief overview of the EMS (Electromagnetic Spectrum)	752
1.21 Launch table of EO missions	758
1.22 Coordinates of satellite launch sites around the world	773

Part A	Atmosphere/Radiation/Aeronomy Missions	775
A.1	ACE+ (Atmosphere Climate Experiment Plus)	775
A.2	ACRIMSAT (Active Cavity Radiometer Irradiance Monitor)	779
A.3	ADM-Aeolus (Atmospheric Dynamics Mission)	781
A.4	AE (Atmosphere Explorer)	786
A.4.1	AE-A (Aeronomy-A, Explorer 17)	786
A.4.2	AE-B (Aeronomy-B, Explorer 32)	787
A.4.3	AE-C (Atmosphere Explorer-C, Explorer 51)	788
A.4.4	AE-D (Atmosphere Explorer-D, Explorer 54)	794
A.4.5	AE-E (Atmosphere Explorer-E, Explorer 55)	794
A.5	AEM-2 (Applications Explorer Mission-2)	795
A.6	Aura Mission (EOS/Chem-1)	796
A.7	C/NOFS (Communication/Navigation Outage Forecast System)	796
A.8	CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations)	804
A.9	CLOUDS (Cloud and Radiation Monitoring Satellite)	806
A.10	CloudSat	814
A.11	COMPASS	818
A.12	Coriolis	820
A.13	CRRES (Combined Release and Radiation Effects Satellite)	824
A.14	Dynamics Explorers (DE-1 and DE-2)	826
A.14.1	DE-1 Instruments (High Altitude Mission)	827
A.14.2	DE-2 Instruments (Low Altitude Mission)	828
A.15	EarthCARE (Earth Clouds, Aerosol and Radiation Explorer)	829
A.16	ERBS (Earth Radiation Budget Satellite)	836
A.17	FBM (French-Brazilian Microsatellite)	838
A.18	FORTE (Fast On-Orbit Recording of Transient Events)	841
A.19	GCOM (Global Change Observation Mission)	845
A.20	GOSAT (Greenhouse gases Observing Satellite)	846
A.21	HCMM (Heat Capacity Mapping Mission)	858
A.22	Megha-Tropiques	858
A.23	ODIN	862
A.24	OrbView-1/Microlab-1	866
A.25	QuikSCAT (Quick Scatterometer Mission)	866
A.26	REX-II (Radiation Experiment Satellite II)	868
A.27	ROCSat-3 / COSMIC / FormoSat-3	869
A.28	SAN MARCO D/L	875
A.29	SCISAT-1/ACE (Science Satellite/Atmospheric Chemistry Experiment)	877
A.30	SORCE (Solar Radiation and Climate Experiment)	880
A.31	TIMED (Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics)	885
A.32	TOMS Missions	889
A.32.1	TOMS-EP	889
A.32.2	TOMS/NSCAT on ADEOS	890
A.32.3	QuikTOMS (Quik Total Ozone Mapping Spectrometer)	891
A.33	Triana	893
A.34	TRMM (Tropical Rainfall Measuring Mission)	898
A.35	UARS (Upper Atmosphere Research Satellite)	903
Part B	Commercial Imaging Satellites	909
B.1	Condor Series of NPO Machinostroyeniya	909
B.1.1	Condor-E (Condor Experimental)	910
B.2	Diamant, OHB Bremen	912
B.3	COSMO-SkyMed (Constellation of 4 SAR Satellites)	915
B.3.1	Space Segment:	916
B.3.2	Orbit of constellation	917
	Sensor complement	919

B.3.3	Background on ASI-CNES agreements	922
B.4	GeoEye-1 (OrbView-5)	925
B.5	Pleiades (Optical Imaging Constellation of CNES)	929
B.5.1	Pleiades spacecraft:	931
B.5.2	Sensor complement: (HiRI)	933
B.6	QuickBird-2	936
B.6.1	Sensor complement:	937
B.7	The QuickBird satellite history	939
B.7.1	EarlyBird	939
B.7.2	QuickBird-1	941
B.8	EROS-A (Earth Remote Observation System-A)	942
B.9	EROS-B Spacecraft	946
B.10	Ikonos-2	948
B.10.1	Sensor complement:	949
B.10.2	Kodak Model 1000 Camera System	951
B.11	OrbView-1/Microlab-1	953
B.12	OrbView-2 (renamed from SeaStar in 1997)	956
	Sensor complement:	957
B.13	OrbView-3	961
B.14	OrbView-4	963
B.15	RapidEye Satellite Constellation	964
B.15.1	Space segment	966
B.15.2	Sensor complement	967
B.15.3	Ground segment	970
B.16	SMOTR (Earth Imaging Constellation)	971
B.17	WorldView-1	975
	WorldView-2	978
Part C Data Collection (Messaging) Systems		985
C.1	Argo (Data Collection in the Global Oceans)	985
C.1.1	Operational Scenario of Argo Floats	986
C.1.2	Argo Data Collection System	987
C.1.3	The Argo Program within IGOS	989
C.2	ARGOS (Data Collection System)	990
C.3	FAISAT (Final Analysis Inc. Satellite)	993
C.4	LLMS (Little LEO Messaging System)	994
C.5	Orbcomm Satellite System	996
C.6	SAFIR (Satellite For Information Relay)	999
C.6.1	SAFIR-1	1000
C.6.2	SAFIR-2	1001
C.7	SCD (Satélite de Coleta de Dados) – Data Collection Program of Brazil	1003
C.7.1	SCD-1 (Satélite de Coleta de Dados-1)	1003
C.7.2	SCD-2 (Satélite de Coleta de Dados-2)	1005
C.8	TEMISAT (Telespazio MicroSatellite)	1008
C.9	Store-and-Forward (S&F) Systems	1012
Part D Earth Observation/Monitoring Missions		1015
D.1	ADEOS (Advanced Earth Observing Satellite)	1015
D.2	ADEOS-II (Advanced Earth Observing Satellite-II)	1022
D.3	ALOS (Advanced Land Observing Satellite)	1027
D.4	ALMAZ Program	1033
D.4.1	COSMOS-1870 (also Kosmos-1870)	1033
D.4.2	ALMAZ-1	1034
D.5	BADR-B	1035
D.6	AlSat-2 (Algeria Satellite-2)	1038

D.7	Bhaskara	1041
D.8	CartoSat-2	1042
D.9	CBERS (China/Brazil - Earth Resources Satellite)	1047
D.9.1	CBERS-1	1048
D.9.2	CBERS-2 (Zi Yuan-1B)	1051
D.9.3	CBERS-3 & 4	1051
D.10	CORONA	1052
D.11	EnMAP (Environmental Monitoring and Analysis Program)	1054
D.12	DubaiSat-1	1060
D.13	ENVISAT (Environmental Satellite)	1072
D.14	EO-1 (Earth Observing-1)	1092
D.15	EOS (Earth Observing System)	1093
D.15.1	Terra Mission (EOS/AM-1)	1094
D.15.2	Aqua Mission (EOS/PM-1)	1104
D.15.3	Aura Mission (EOS/Chem-1)	1110
D.16	ESE (Earth Science Enterprise)	1117
D.17	ERS-1 (European Remote-Sensing Satellite)	1120
D.18	ERS-2	1127
D.19	Flying Laptop	1131
D.20	Glory	1135
D.21	HY-1A (Haiyang-1/Ocean-1A)	1144
D.22	HY-1B (Haiyang-1B) / Ocean-1B	1146
D.23	ICESat (Ice, Cloud and land Elevation Satellite)	1150
D.24	IRS (Indian Remote Sensing Satellites)	1154
D.24.1	IRS-1A	1155
D.24.2	IRS-1B	1156
D.24.3	IRS-1E (P1)	1157
D.24.4	IRS-P2	1157
D.24.5	IRS-1C/1D	1158
D.24.6	IRS-P3	1160
D.24.7	IRS-P4 (OceanSat-1)	1162
D.24.8	IRS-P5 (CartoSat-1)	1166
D.24.9	IRS-P6 (ResourceSat-1)	1167
D.25	JERS-1 (Japan Earth Resources Satellite)	1168
D.26	KITSAT Program	1171
D.26.1	KITSAT-2 (Korea Institute of Technology Satellite-2)	1171
D.26.2	KITSAT-3 (Korea Institute of Technology Satellite-3)	1172
D.26.3	K-4 (KAISTSAT-4)	1175
D.27	KOMPSAT (Korea Multi-Purpose Satellite)	1175
D.27.1	KOMPSAT-1 (Korea Multi-Purpose Satellite-1)	1175
D.27.2	KOMPSAT-2 (Korea Multi-Purpose Satellite-2)	1179
D.28	LANDSAT	1181
D.28.1	Landsat-1 to -5	1183
D.28.2	Landsat-6	1186
D.28.3	Landsat-7	1188
D.29	Landsat-8 / LDCM (Landsat Data Continuity Mission)	1193
D.30	Lewis and Clark Missions	1205
D.30.1	Lewis S/C	1205
D.30.2	Clark S/C	1209
D.31	MACSat / RazakSat	1212
D.32	MIOsat (MISSIONE Ottica su microSatellite)	1219
D.33	Monitor-E1	1232
D.34	MOS (Marine Observation Satellite)	1233
D.35	MTI (Multispectral Thermal Imager)	1235
D.36	NigeriaSat-2	1238

D.37	OKEAN-O	1244
	D.37.1 Experimental Cosmos Program	1244
	D.37.2 OKEAN-O1 Operational Series	1246
	D.37.3 OKEAN-O Series	1248
D.38	RASAT (Earth Observation Satellite)	1253
	D.38.1 Sich-1M (Modified)	1260
D.39	OceanSat-2	1265
D.40	OrbView-2/SeaStar	1272
D.41	PRIRODA	1273
	PRISMA (Hyperspectral Precursor and Application Mission)	1284
D.42	RADARSAT	1297
	D.42.1 RADARSAT-1	1297
	D.42.2 AMM-1 (Antarctic Mapping Mission-1)	1301
	D.42.3 AMM-2 (Antarctic Mapping Mission-2)	1302
	D.42.4 RADARSAT-2	1303
	D.42.5 RADARSAT-2/3 Topographic Mission	1307
D.43	RADCAL (Radar Calibration Satellite)	1309
D.44	RESURS-F	1310
D.45	RESURS-O	1313
D.46	ResourceSat-2	1316
D.47	RISAT (Radar Imaging Satellite)	1323
D.48	ROCSat (Republic of China Satellite)	1329
	D.48.1 ROCSat-1	1329
	D.48.2 ROCSat-2	1332
D.49	SAC-C (Satélite de Aplicaciones Científicas-C)	1335
D.50	SAC-D (Satélite de Aplicaciones Científicas-D)/Aquarius Mission	1340
D.51	SARAL (Satellite with ARGOS and ALtiKa)	1349
D.52	SEASAT	1359
D.53	SMOS (Soil Moisture and Ocean Salinity)	1364
	D.53.1 SMOS campaigns (technology verification)	1371
	D.53.2 MIRAS (Microwave Imaging Radiometer with Aperture Synthesis)	1371
D.54	Spain-DMC	1372
D.55	SPOT (Système Pour l'Observation de la Terre)	1376
	D.55.1 SPOT-3	1378
	D.55.2 SPOT-4	1379
	D.55.3 SPOT-5	1384
D.56	SSR1 (Satelite de Sensoriamento Remoto)	1390
D.57	TAIKI EO Mission	1391
D.58	TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurement)	1401
D.59	TecSAR (SAR Technology Demonstration Satellite)	1414
D.60	TerraSAR-X Mission	1419
	D.60.1 Space segment:	1420
	D.60.2 Ground segment:	1424
	D.60.3 TSX-SAR (TerraSAR-X SAR instrument)	1427
	D.60.4 Secondary payloads of TerraSAR-X (TOR, LRR, LCT)	1435
D.61	THEOS (Thailand Earth Observation System)	1442
D.62	UoSAT/SSTL Microsatellite Missions	1448
	D.62.1 UoSAT-1 (University of Surrey Satellite-1)	1450
	D.62.2 UoSAT-2	1450
	D.62.3 UoSAT-3 (HealthSat-1)	1451
	D.62.4 UoSAT-4	1451
	D.62.5 UoSAT-5	1451
	D.62.6 KITSAT-1 (Korea Institute of Technology Satellite)	1452
	D.62.7 S-80/T	1452
	D.62.8 HealthSat-2	1453

D.62.9	PoSAT-1 (Portuguese Satellite)	1453
D.62.10	KITSAT-2	1455
D.62.11	CERISE	1455
D.62.12	FASat-Alfa (Fuerza Aerea Satellite - Alfa)	1455
D.62.13	FASat-Bravo (Fuerza Aerea Satellite - Bravo)	1457
D.62.14	UoSAT-12	1457
D.62.15	TMSat (Thai-Microsatellite)	1462
D.62.16	SNAP (Surrey Nanosatellite Applications Program)	1464
D.62.17	SNAP-1	1464
D.62.18	Tsinghua-1	1467
D.62.19	TiungSat	1468
D.62.20	DMC (Disaster Monitoring Constellation)	1470
D.62.21	TOPSAT (Tactical Optical Satellite)	1470
Part E Atmosphere/Radiation/Aeronomy Missions		1471
E.1	CHAMP (Challenging Minisatellite Payload)	1471
E.2	CryoSat	1478
E.3	EGS (Experimental Geodetic Satellite, Ajisai)	1486
E.4	ETALON	1487
E.5	GEO-1K	1488
E.6	GEOS (GEOstationary Satellite)	1488
E.6.1	GEOS-1	1488
E.6.2	GEOS-2	1489
E.7	GEOS (Geodetic Earth Orbiting Satellite) Program	1489
E.7.1	GEOS-1 (Geodetic Earth Orbiting Satellite)	1490
E.7.2	GEOS-2 (Geodetic Earth Orbiting Satellite)	1492
E.7.3	GEOS-3 (Geodynamics Experimental Ocean Satellite)	1493
E.8	GEOSAT (Geodetic/Geophysical Satellite)	1494
E.9	GFO-1 (Geosat Follow-On Program)	1495
E.10	GFZ-1 (GeoForschungsZentrum-1 Geodesy Satellite)	1497
E.11	GOCE (Gravity field and steady-state Ocean Circulation Explorer)	1498
E.11.1	GOCE/GRACE (Gravity Recovery And Climate Experiment) mission comparison	1508
E.12	GP-B (Gravity Probe B)	1509
	Some background on GP-B:	1510
E.12.1	Mechanical Systems	1512
E.12.2	Experiment Payload	1513
E.12.3	Background on Gravity Probe A (GP-A) Mission	1516
E.13	GRACE (Gravity Recovery And Climate Experiment)	1517
	GRACE spacecraft:	1519
E.14	Jason (Joint Altimetry Satellite Oceanography Network)	1522
E.14.1	Jason-1	1523
E.14.2	Sensor Complement:	1524
E.15	LAGEOS-I (Laser Geodynamics Satellite)	1527
E.15.1	LAGEOS-II	1528
E.16	MAGSAT	1529
E.17	MIMOSA	1530
E.18	Ørsted	1533
E.19	Starlette	1542
E.20	Stella	1542
E.21	Swarm (Geomagnetic LEO Constellation)	1543
E.22	THEMIS (Time History of Events and Macroscale Interactions during Substorms)	1553
E.23	TOPEX/Poseidon (Topography Experiment/Poseidon)	1566
E.23.1	DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite)	1570

E.23.2	T/P Data	1572
E.23.3	Some T/P Results	1572
E.24	WESTPAC (Western Pacific Satellite)	1573

Part F Meteorology - GEO (Geosynchronous Earth Orbit) Missions 1575

F.1	Elektro-M-1(Elektro-Modified-1)	1575
F.2	Feng-Yun-2 (Geostationary Satellite Series)	1577
F.2.1	FY-2A (Feng-Yun-2A)	1578
F.2.2	FY-2B (Feng-Yun-2B)	1579
F.3	GMS (Geostationary Meteorological Satellite)	1580
F.3.1	GMS Data Collection System (DCS)	1581
F.4	GOES (Geostationary Operational Environmental Satellite)	1582
F.4.1	NOAA-GOES Data Collection System (DCS)	1585
F.4.2	NOAA-GOES SEM Instruments	1588
F.4.3	NOAA-GOES Second Generation	1589
F.4.4	GOES-N-Q Series Spacecraft and Instruments	1596
F.5	GOMS (Geostationary Operational Meteorological Satellite)	1598
F.5.1	Radio Complex for Data Collection, Transmission and Relay	1601
F.6	INSAT	1602
F.6.1	INSAT-1 Satellite Series	1602
F.6.2	INSAT-2 Satellite Series	1603
F.6.2.1	INSAT-2E	1605
F.6.3	INSAT-3 Satellite Series	1609
F.6.3.1	INSAT-3B	1610
F.6.3.2	INSAT-3A	1610
F.7	Kalpana-1/MetSat-1 (Meteorological Satellite-1)	1610
F.8	METEOSAT	1614
F.8.1	Meteosat Data Collection System (DCS)	1617
F.8.2	Meteosat DCP Retransmission System	1620
F.8.3	MOSAIC	1621
F.9	MSG (METEOSAT Second Generation)	1622
F.9.1	MSG Ground Segment (Stations)	1629
F.9.2	MSG Communication Services and Data Distribution	1630
F.10	MTSAT (Multifunction Transport Satellite)	1631
F.10.1	MTSAT-1R	1632
F.10.1.1	Aeronautical Mission	1633
F.10.1.2	Meteorological Mission	1634
F.10.1.3	DCS (Data Collection System)	1637

Part G Meteorology - LEO (Low Earth Orbit) Missions 1639

G.1	DMSP (Defense Meteorological Satellite Program)	1639
G.1.1	Description of Block 5D-2 and 5D-3 Sensors	1642
G.1.2	Space Environment Sensors	1648
G.1.3	Early Sensors of the DMSP Program	1653
G.1.4	DMSP Data Availability - Visible and Infrared Imagery	1654
G.2	EPS (EUMETSAT Polar System)	1656
G.2.1	MetOp-1 Satellite	1657
G.2.2	MetOp-1 Sensor Complement	1661
G.3	Feng-Yun-1 (Polar Orbiting Satellite Series)	1672
G.3.1	FY-1A, -1B	1672
G.3.2	Feng-Yun-1C and -1D	1674
G.3.3	FY-3 (Feng-Yun-3) Satellite Series	1675
FY-3	(Feng-Yun-3) Polar-orbiting Meteorological Satellite Series	1680
G.4	METEOR-1 Series	1690
G.5	METEOR-2 Series	1691

G.6	METEOR-Priroda Series	1691
G.7	METEOR-3 Series	1693
G.8	Meteor-3M Series	1699
G.8.1	Meteor-3M-1	1699
G.8.2	Meteor-3M-2	1707
G.9	NPP (NPOESS Preparatory Project)	1713
Satellite system overview:	.....	1714
Sensor complement:	.....	1716
Technology demonstrations:	.....	1720
Ground Segment of NPP:	.....	1720
G.10	NPOESS (National Polar-orbiting Operational Environmental Satellite System) ..	1720
G.10.1	NPOESS Transition Period Overview	1721
G.10.2	NPOESS System Overview	1723
G.10.3	System architecture:	1723
G.10.4	The NPOESS Satellite	1725
G.10.5	NPOESS sensor complement	1727
G.10.6	Auxiliary payloads of NPOESS	1741
G.10.7	SESS (Space Environment Sensor Suite)	1743
G.10.8	FTS (Field Terminal Segment)	1743
G.11	TIROS Meteorological Satellite Series (with the POES Program)	1747
G.11.1	TIROS-1 (TIROS-A)	1747
G.11.2	TIROS-2 (TIROS-B)	1748
G.11.3	TIROS-3 (TIROS-C)	1749
G.11.4	TIROS-4 (TIROS-D)	1750
G.11.5	TIROS-5 (TIROS-E)	1750
G.11.6	TIROS-6 (TIROS-F)	1750
G.11.7	TIROS-7 (TIROS-G)	1751
G.11.8	TIROS-8 (TIROS-H)	1751
G.11.9	TIROS-9 (TIROS-I)	1752
G.11.10	TIROS-10	1753
G.12	TOS/ESSA Satellite Series (2nd Generation)	1753
G.12.1	ESSA-1 (TOS-1)	1753
G.12.2	ESSA-2 (TOS-2)	1754
G.12.3	ESSA-3 (TOS-3)	1755
G.12.4	ESSA-4 (TOS-4)	1755
G.12.5	ESSA-5 (TOS-5)	1755
G.12.6	ESSA-6 (TOS-6)	1756
G.12.7	ESSA-7 (TOS-7)	1756
G.12.8	ESSA-8 (TOS-8)	1756
G.12.9	ESSA-9 (TOS-9)	1757
G.13	ITOS (Improved TIROS Operational System)	1757
G.13.1	NOAA-1 (ITOS-A, also known as ITOS-1 and TIROS-M)	1757
G.13.2	NOAA-2 (ITOS-D)	1759
G.13.2.1	NOAA-3 (ITOS-F)	1759
G.13.3	NOAA-4 (ITOS-G)	1760
G.13.4	NOAA-5 (ITOS-H)	1760
G.14	TIROS-N (4th Generation) Satellite Series	1760
G.14.1	TIROS-N Satellite	1761
G.14.1.1	NOAA-6 (NOAA-A)	1762
G.14.2	NOAA-B	1762
G.14.3	NOAA-7 (NOAA-C)	1762
G.14.4	NOAA-8 (NOAA-E)	1766
G.14.5	NOAA-9 (NOAA-F)	1766
G.14.6	NOAA-10 (NOAA-G)	1766

G.14.7	NOAA-11 (NOAA-H)	1767
G.14.8	NOAA-12 (NOAA-D)	1767
G.14.9	NOAA-13 (NOAA-I)	1767
G.14.10	NOAA-14 (NOAA-J)	1768
G.14.11	Sensor Descriptions of 4th Generation Series	1768
G.14.12	SEM (Space Environment Monitor)	1771
G.15	5th Generation Satellites of NOAA-POES Series	1772
G.15.1	Sensors for the POES K, L, M, N, N' Series	1774
G.15.2	SEM-2 (Space Environment Monitor-2)	1779
G.15.3	IJPS (Initial Joint Polar System)	1780
G.15.4	ARGOS on NOAA-POES Satellites	1782
Part H Satellite Radionavigation Systems		1783
H.1	CNSS (Compass/BeiDou Navigation Satellite System)	1783
H.1.1	BeiDou-1 regional satellite navigation system	1784
H.1.2	Compass/BeiDou-2 global satellite navigation constellation	1786
H.2	GALILEO	1789
H.2.1	GALILEO System Architecture	1791
H.2.2	GALILEO User Segment and Services	1793
H.2.3	GALILEO Signal Baseline	1795
H.2.4	GCS (Ground Control Segment)	1797
H.2.5	IDS (Integrity Determination Segment)	1798
H.2.6	GALILEO Satellite Design Requirements	1801
H.3	GNSS-1 Augmentation Systems	1804
H.3.1	WAAS (Wide Area Augmentation System)	1806
H.3.2	EGNOS (European Geostationary Navigation Overlay System)	1808
H.3.2.1	EGNOS System Test Bed (ESTB)	1810
H.3.3	MSAS (Multi-Transport Satellite Augmentation System)	1811
H.4	GLONASS	1811
H.5	GPS (NAVSTAR-GPS)	1814
H.5.1	GPS Space Segment	1815
H.5.1.1	Block I Satellites	1818
H.5.1.2	Block II Satellites (NAVSTAR II-1 to II-8)	1819
H.5.1.3	Block IIA Satellites (NAVSTAR IIA-10 to IIA-27)	1820
H.5.1.4	Block IIR (Replacement Operational Satellites)	1820
H.5.1.5	Block IIR-M Spacecraft Modernization	1822
H.5.1.6	Block IIF (II Follow-on) Satellites	1824
H.5.2	GPS Control Segment	1828
H.5.3	GPS User Segment	1829
H.5.3.1	Fundamental GPS Observables	1830
H.5.3.2	Availability of GPS/GLONASS Systems	1831
H.5.3.3	GPS Applications	1832
H.5.3.4	Some GPS Orbit and Attitude Instruments	1833
H.5.3.5	IGS (International GPS Service for Geodynamics)	1836
H.5.3.6	CIGNET	1837
H.5.4	DGPS (Differential GPS)	1837
H.6	MTSAT (Multifunction Transport Satellite)	1838
H.7	Transit - Navy Navigation Satellite System (NNSS)	1839
H.8	Summary of Microwave Tracking Systems	1842
H.8.1	DORIS Tracking System	1843
H.8.2	PRARE Tracking System	1846
H.9	QZSS (Quasi Zenith Satellite System)	1849
Part I Satellite Event, Emergency & Environmental Monitoring		1865
I.1	BIRD (Bi-Spectral Infrared Detection)	1865

I.2	DEMETER (Detection of Electromagnetic Emissions transmitted from Earthquake Regions)	1869
I.3	DMC (Disaster Monitoring Constellation)	1869
I.3.1	AlSat-1 (Algeria Satellite-1)	1871
I.3.2	BilSat-1 (BILTEN Satellite-1)	1873
I.3.3	NigeriaSat-1	1876
I.3.4	UK-DMC (United Kingdom – Disaster Monitoring Constellation)	1878
I.3.5	Beijing-1 (China DMC+4)	1885
I.4	Fuego/FOC (Fire Observation Constellation)	1892
I.4.1	Fuego System Concept	1893
I.4.2	FuegoSat	1897
I.5	GMES (Global Monitoring for Environment and Security)	1897
Earth observation: GMES Space Component	1899	
I.6	GMES: Sentinel-1 Mission	1905
I.7	GMES: Sentinel-2 Mission	1914
I.8	GMES: Sentinel-3 Mission	1922
I.9	LEAP (Low-frequency Earthquake Precursor) microsatellite	1932
I.10	NEO (Near Earth Object) Hazard Assessment	1937
I.10.1	Overview of space missions with comet or asteroid encounters	1938
I.10.2	Search of NEOs by spaceborne missions	1940
I.11	Search & Rescue (S&R) Satellite Systems	1942
I.11.1	COSPAS-S&RSAT Constellation	1942
I.11.1.1	Alert Signal Devices (User Segment)	1943
I.11.1.2	Satellite Payloads (Space Segment)	1943
I.11.1.3	COSPAS-S&RSAT Ground Segment	1944
I.11.2	GEOS&R (Geostationary Search & Rescue)	1945
I.11.3	SAS&R (Satellite Aided Search and Rescue)	1945
I.12	SAR-Lupe Constellation	1946
 Part J Shuttle - Selected Missions and Payloads		1949
J.1	ASTRO-SPAS (Astronomy Platform - Shuttle Pallet Satellite)	1949
J.1.1	ORFEUS-SPAS-1	1949
J.1.2	CRISTA-SPAS-1	1950
J.1.3	ORFEUS-SPAS-2	1953
J.1.4	CRISTA-SPAS-2	1954
J.2	ATLAS (Atmospheric Laboratory for Application and Science)	1954
J.3	Bitsy-SX (Bitsy-Spacecraft in Future-X)	1957
J.4	CIRRIS (Cryogenic Infrared Radiance Instrumentation for Shuttle)	1958
J.5	EURECA (European Retrievable Carrier)	1959
J.5.1	EURECA-1 Mission	1959
J.6	FREESTAR (Fast Reaction Experiments Enabling Science, Technology, Applications & Research)	1962
IAE (Inflatable Antenna Experiment) on Shuttle Flight STS-77	1966	
J.7	IPS (Instrument Pointing System)	1975
J.8	ISIR (Infrared Spectral Imaging Radiometer)	1980
J.9	LDEF (Long Duration Exposure Facility)	1981
J.10	LFC (LARGE FORMAT CAMERA)	1985
J.11	LITE (Lidar In-Space Technology Experiment)	1985
J.12	MACH-1 (Multiple Application Customized Hitchhiker-1)	1986
J.13	MAPS (Measurement of Air Pollution from Satellites)	1989
J.14	MOMS-01 (Modular Optoelectronic Multispectral Scanner)	1990
J.15	MOMS-02 (Modular Optoelectronic Multispectral Scanner)	1992
J.16	SAC (Satélite de Aplicaciones Científicas)	1994
J.17	SAC -A (Satélite de Aplicaciones Científicas-A)	1994
J.18	SHIMMER (Spatial Heterodyne Imager for Mesospheric Radicals)	1995

J.19	SLA (Shuttle Laser Altimeter)	1997
	J.19.1 SLA-1	1997
	J.19.2 SLA-2	1998
J.20	SPARTAN (Shuttle Pointed Autonomous Research Tool for Astronomy)	1998
	J.20.1 SPARTAN-1	1999
	J.20.2 SPARTAN-Halley	1999
	J.20.3 SPARTAN-201	1999
	J.20.4 SPARTAN-204	2000
	J.20.5 SPARTAN-206	2001
	J.20.6 SPARTAN-207	2002
	J.20.7 SPARTAN-250 Carrier System	2002
	J.20.8 SPARTAN-251	2002
	J.20.9 SPARTAN-401	2002
J.21	SIR-A (Shuttle Imaging Radar)	2003
J.22	SIR-B	2004
J.23	SIR-C/X-SAR	2005
J.24	Spacelab-1	2008
J.25	Spacelab-3	2009
J.26	Shuttle EO Imaging Cameras	2009
	J.26.1 Shuttle Film Camera Systems	2010
	J.26.2 IMAX Space Cameras	2011
	J.26.3 IMAX-3D Space Cameras	2011
	J.26.4 ICBC (IMAX Cargo Bay Camera)	2012
	J.26.5 SPSR (Space Portable SpectroReflectometer)	2013
J.27	SRTM (Shuttle Radar Topography Mission)	2014
J.28	SSBUV (Shuttle Solar Backscatter Ultraviolet Spectrometer)	2017
Part K Space Science/Solar-Terrestrial Missions		2019
K.1	ACE (Advanced Composition Explorer)	2019
K.2	ACTIVE (AKTIVNY-IK)	2021
	K.2.1 Subsatellite Magion-2 (C2-AK)	2024
K.3	ALEXIS (Array of Low-Energy X-Ray Imaging Sensors)	2026
K.4	AMPTE (Active Magnetosphere Tracer Explorers)	2029
	K.4.1 IRM Instrumentation (Sensors)	2032
	K.4.2 UKS Instrumentation (Sensors)	2033
	K.4.3 CCE Instrumentation (Sensors)	2033
K.5	APEX (Active Plasma Experiment)	2033
	K.5.1 APEX Subsatellite (Magion-3) Scientific Payload	2035
K.6	ASTRID	2036
	K.6.1 ASTRID-1	2036
	K.6.2 ASTRID-2	2038
K.7	CLuster (Four S/C Mission in Concert with SOHO)	2039
	K.7.1 Cluster-I	2039
	K.7.2 Cluster-II	2044
K.8	CORONAS-I	2046
	K.8.1 CORONAS-F	2050
K.9	Coronas-Photon	2052
K.10	DSP (Double Star Project)	2071
	DSP ground segment:	2078
K.11	Equator-S	2079
K.12	EXOS (Exospheric Observations)	2082
	K.12.1 EXOS-A (Kyokko)	2082
	K.12.2 EXOS-B (Jikiken)	2082
	K.12.3 EXOS-C (Ohzora = Sky)	2084
	K.12.4 EXOS-D (Akebono)	2085

K.13	FREJA	2089
K.14	Genesis (Solar-Wind Sample Return Mission)	2093
K.15	GEOTAIL	2099
K.16	RHESSI (Reuven Ramaty High Energy Solar Spectroscopic Imager)	2103
HSO	(Herschel Space Observatory)	2105
K.17	IBEX (Interstellar Boundary Explorer)	2157
K.18	IMAGE (Imager for Magnetopause-to-Aurora Global Exploration)	2175
K.19	IMP-8 (International Monitoring Platform)	2181
K.20	INTERBALL	2184
	K.20.1 “Auroral Probe” Sensors	2185
	K.20.2 “Tail Probe” Sensors	2187
K.21	ISEE (International Sun-Earth Explorer)	2190
	K.21.1 ISEE-1 and -2 Mission	2190
	K.21.2 ISEE-3 Mission	2192
K.22	POLAR	2195
	K.22.1 SAC-B (Satélite de Aplicaciones Científicas-B)	2200
K.23	SDO (Solar Dynamics Observatory)	2201
	K.23.1 SDO ground system:	2220
K.24	SME (Solar Mesosphere Explorer)	2222
K.25	SMEX (Small Explorer Program)	2224
	K.25.1 SAMPEX (Solar Anomalous and Magnetospheric Particle Explorer)	2224
	K.25.2 FAST (Fast Auroral Snapshot Explorer)	2227
	K.25.3 TRACE (Transition Region and Coronal Explorer)	2229
K.26	SMM (Solar Maximum Mission)	2231
K.27	SOHO (Solar and Heliospheric Observatory)	2235
K.28	SOLAR–A/Yohkoh (X–ray Solar Observatory)	2240
K.29	Solar-B	2243
K.30	STEREO (Solar-Terrestrial Relations Observatory)	2245
K.31	TWINS (Two Wide-angle Imaging Neutral-atom Spectrometers)	2254
K.32	Ulysses	2256
K.33	Viking	2260
K.34	WIND	2263
Part L Space Stations		2267
L.1	ISS (International Space Station)	2267
L.2	ISS Utilization - Selected Payloads and Instruments	2270
	L.2.1 ACCESS (Advanced Cosmic-Ray Composition Experiment for Space Station)	2270
	L.2.2 ACES (Atomic Clock Ensemble in Space)	2271
	L.2.3 AMS (Alpha Magnetic Spectrometer)	2271
	L.2.4 ARISS (Amateur Radio on the International Space Station)	2272
	L.2.5 CRESPO (Coral Reef Ecosystem Spectro-Photometric Observatory)	2272
	L.2.6 EUTEF (European Technology Exposure Facility)	2272
	L.2.7 FOCUS (Fire Detection and Analysis Sensor System)	2273
	L.2.8 GTS (Global Transmission Services)	2274
	L.2.9 LCDE (Laser Communications Demonstration Equipment)	2274
	L.2.10 PARCS (Primary Atomic Reference Clock in Space)	2276
	L.2.11 PET (Photovoltaic Engineering Testbed)	2276
	L.2.12 RACE (Rubidium Atomic Clock Experiment)	2277
	L.2.13 SAGE-III (Stratospheric Aerosol and Gas Experiment III)	2277
	L.2.14 SEDA-AP (Space Environment Data Acquisition equipment-Attached Payload)	2278
	L.2.15 SMILES (Superconducting Submillimeter-wave Limb-Emission Sounder)	2279
	L.2.16 Solar-A (Solar Monitoring Observatory)	2282
	L.2.16.1 SOVIM (Solar Variability and Irradiance Monitor)	2282

L.2.16.2	SOLSPEC (Solar Spectral Irradiance Measurements)	2283
L.2.16.3	SOL-ACES (Solar Auto-Calibrating EUV/UV Spectrophotometers)	2283
L.2.17	SUMO (Superconducting Microwave Oscillator)	2283
L.2.18	WORF (Window Observational Research Facility)	2284
L.3	MIR-1 Orbital Station	2284
L.4	Salyut Space Station	2289
L.5	Skylab Space Station	2290
L.5.1	EREP sensor complement	2297
L.5.2	Solar payload complement	2304
L.5.3	Some pioneering Skylab achievements	2317
Part M Technology Missions		2319
M.1	ACTS (Advanced Communications Technology Satellite)	2319
	AISSat-1 (Automatic Identification System Satellite-1)	2326
M.2	ANDE (Atmospheric Neutral Density Experiment)	2333
M.3	ARGOS (Advanced Research and Global Observation Satellite)	2345
M.4	ARTEMIS (Advanced Relay and Technology Mission Satellite)	2354
M.5	Bitsy-SX (Bitsy-Spacecraft in Future-X)	2360
M.6	CanX-4&5 (Canadian Advanced Nanospace eXperiment-4&5)	2361
M.7	CanX-6 (Canadian Advanced Nanosatellite eXperiment-6) / NTS	2369
M.8	CASSIOPE (Cascade SmallSat and Ionospheric Polar Explorer)	2374
M.9	DART (Demonstration for Autonomous Rendezvous Technology)	2379
M.10	DODGE (Department of Defense Gravity Experiment)	2383
M.11	DS1 (Deep Space 1)	2384
M.12	EO-1 (Earth Observing-1)	2391
M.12.1	Sensor Complement	2393
M.12.2	Demonstration of seven new technologies on EO-1	2398
M.13	EO-3 (Earth Observing-3, GIFTS-IOMI Mission)	2401
M.14	ETS (Engineering Test Satellite)	2407
M.14.1	ETS-VII (Engineering Test Satellite VII)	2407
M.14.2	ETS-VIII (Engineering Test Satellite VIII)	2410
M.15	FedSat-1 (Federation Satellite One)	2413
M.16	Foton-M3 Mission / YES2 and OWLS Experiments	2417
M.16.1	YES2 (Young Engineers' Satellite-2)	2424
M.16.2	OWLS (Optical Wireless Link intra-Satellite)	2429
M.17	Genesis inflatable space complex program of Bigelow Aerospace	2431
M.17.1	Genesis-1	2433
M.17.2	Genesis-2	2436
M.18	GeoSTAR (Geostationary Synthetic Thinned Aperture Radiometer)	2439
M.19	JC2Sat-FF (Japan Canada Joint Collaboration Satellites - Formation Flying)	2445
M.20	LDEF (Long Duration Exposure Facility)	2455
M.21	LISA Pathfinder (LPF) Mission	2473
M.22	MDS (Mission Demonstration Satellite)	2487
M.22.1	MDS-1	2487
M.23	MicroLabSat	2490
Spacecraft:	. . . . .	2490
Sensor/experiment complement:	. . . . .	2492
M.24	MightySat	2495
M.24.1	MightySat I	2496
M.24.2	MightySat II.1 (Sindri)	2497
M.25	MINISAT	2502
M.25.1	MINISAT-01	2502
M.26	MITA (Minisatellite Italiano di Tecnologia Avanzata)	2504
M.27	MSX (Midcourse Space Experiment)	2506

M.28 Myriade (CNES Microsatellite Program)	2514
M.28.1 DEMETER	2515
M.28.2 Microscope	2518
Spacecraft:	2519
Sensor/payload complement: (SAGE, DFACS)	2519
M.28.3 PARASOL	2523
M.28.4 Picard	2524
Nano-JASMINE	2526
NanoSail-D (NanoSail-Demonstration)	2536
M.29 Nimbus	2545
M.29.1 Nimbus-1	2547
M.29.2 Nimbus-2	2548
M.29.3 Nimbus-3	2549
M.29.4 Nimbus-4	2551
M.29.5 Nimbus-5	2553
M.29.6 Nimbus-6	2555
M.29.7 Nimbus-7	2557
M.30 OICETS (Optical Inter-orbit Communications Engineering Test Satellite)	2561
ORS (Orbital Recovery System)	2564
M.31 PICOSat (STP)	2574
M.32 PRISMA (Prototype Research Instruments and Space Mission technology Advancement)	2578
M.33 PROBA (Project for On-Board Autonomy)	2588
M.34 PROBA-2 (Project for On-Board Autonomy-2)	2597
M.35 RADCAL (Radar Calibration Satellite)	2611
M.36 SERVIS (Space Environment Reliability Verification Integrated System)	2612
SERVIS-1 Mission	2613
M.36.1 SERVIS-2 Mission	2619
M.37 SJ (Shi Jian Program)	2621
M.37.1 SJ-2 (Shi Jian - 2)	2622
M.37.2 SJ-4 (Shi Jian - 4)	2624
M.37.3 SJ-5 (Shi Jian - 5)	2624
M.38 SMART-1 (Small Mission for Advanced Research in Technology)	2626
M.39 SOHLA-1 (Space Oriented Higashiosaka Leading Association-1)	2633
M.40 SPORT (Small Payload Orbit Transfer)	2643
M.41 SpriteSat	2645
M.42 ST5 (Space Technology 5)	2651
M.43 STARS-1 (Space Tethered Autonomous Robotic Satellite-1)	2656
M.44 STEX (Space Technology Experiment)	2666
M.45 STSat-1 (Science and Technology Satellite-1)	2675
STSat-2 (Science and Technology Satellite-2)	2678
M.46 STPSat-1 (Space Test Program Satellite-1)	2683
M.47 STRV (Space Technology Research Vehicle)	2688
M.47.1 STRV-1a and -1b	2688
M.47.1.1 STRV-1a Sensor/Experiment Complement	2689
M.47.1.2 STRV-1b Sensor/Experiment Complement	2691
M.47.2 STRV-1c and -1d	2693
M.47.2.1 STRV-1c Sensor/Experiment Complement	2693
M.47.2.2 STRV-1d Sensor/Experiment Complement	2696
M.48 TacSat-1 (Tactical Satellite)	2698
M.49 TacSat-2 / Roadrunner	2700
M.50 TacSat-3 (Tactical Satellite-3)	2704
TacSat-4 (Tactical Satellite-4)	2720
M.51 TARANIS (Tool for the Analysis of RAdiations from lightNings and Sprites)	2741
M.52 TEAMSAT	2749

M.53	Tether Missions/Experiments	2752
M.53.1	ASTOR (Advanced Safety Tether Operation and Reliability)	2754
M.53.2	BOLAS (Bistatic Observations with Low Altitude Satellites)	2755
M.53.3	METS (MIR Electrodynamic Tether System)	2755
M.53.4	OEDIPUS	2755
M.53.5	PMG (Plasma Motor Generator)	2755
M.53.6	ProSEDS (Propulsive Small Expendable Deployer System)	2756
M.53.7	SEDS (Small Expendable Deployer System)	2756
M.53.8	STEP-AIRSEDS	2757
M.53.9	STEPS (Station Tethered Express Payload System)	2757
M.53.10	TiPS (Tether Physics and Survivability)	2758
M.53.11	TSE (Tether System Experiment)	2759
M.53.12	TSS (Tethered Satellite System)	2760
M.54	TOPSat	2761
M.55	TSX-5 (Tri-Service Experiments Mission 5)	2765
M.55.1	STRV-2 (Space Technology Research Vehicle-2)	2765
M.55.2	CEASE (Compact Environmental Anomaly Sensor Experiment)	2769
M.56	WEOS (Whale Ecology Observation Satellite)	2770
Spacecraft:	.....	2770
Localization experiment:	.....	2771
M.57	WINDS (Wideband InterNetworking engineering test and Demonstration Satellite)	2772
M.58	X-Sat (Minisatellite Technology Demonstration Mission)	2783
M.59	XSS (Experimental Spacecraft System)	2786
M.59.1	XSS-10 (Experimental Spacecraft System-10)	2787
XSS-11	(Experimental Spacecraft System-11)	2788
 Part N University/Student-Developed Satellites & Payloads		2793
N.1	ALMASat-1 (Alma Mater Satellite-1)	2794
N.2	ANUSat (Anna University Microsatellite)	2800
N.3	ASUSat-1 (Arizona State University Satellite 1)	2801
N.4	BeeSat (Berlin Experimental Educational Satellite)	2803
N.5	BEOSAT (Braunschweig's Earth Observation Satellite)	2806
N.6	BREM-SAT 1	2811
BRITE	(BRiGht-star Target Explorer) Constellation / CanX-3	2813
N.7	CanX-2 (Canadian Advanced Nanosatellite eXperiment-2)	2824
N.8	CHIPSat (CHIPS Satellite)	2828
N.9	CX-I (Citizen Explorer-I)	2831
N.9.1	On-board Sensor Complement	2832
N.9.2	Ground Instruments	2833
N.9.3	Technology Demonstrations	2834
N.9.4	Data Distribution Scheme and User Involvement	2834
Delfi-C3	(Triple-unit CubeSat Configuration of TU Delft)	2835
N.10	FalconSat-1	2839
N.11	FalconSat-2	2840
N.12	JAWSAT (Joint Airforce Academy / Weber State University Satellite)	2842
N.13	Kolibri-2000	2844
N.14	NanoSat	2847
N.15	NavGold	2848
N.16	Munin	2850
N.17	NUSAT (Northern Utah Satellite)	2852
N.18	OPAL (Orbiting Picosat Automatic Launcher)	2853
N.18.1	Sensor/payload complement	2854
N.18.2	StenSat	2855
N.18.3	PICOSAT1.0	2856
N.18.4	Artemis	2857

N.19	PANSAT (Petite Amateur Navy SATellite)	2858
N.20	PCSat (Prototype Communications Satellite)	2859
N.21	PRISM (Picosatellite for Remote-sensing and Innovative Space Missions)	2862
	QSat (Kyushu Satellite)	2866
N.22	SAPPHIRE (Stanford AudioPhonic Photographic IR Experiment)	2875
N.23	SEDSAT-1 (Students for the Exploration & Development of Space)	2877
N.24	Sputnik-II	2879
N.25	STARSHINE (Student-Tracked Atmospheric Research Satellite for Heuristic International Networking Equipment)	2879
	N.25.1 STARSHINE-1	2879
	N.25.2 STARSHINE-2	2881
	N.25.3 STARSHINE-3	2881
N.26	STEDI (Student Explorer Demonstration Initiative)	2883
	N.26.1 SNOE (Student Nitric Oxide Explorer)	2883
	N.26.2 TERRIERS	2886
	N.26.3 CATSAT (Cooperative Astrophysical and Technology Satellite)	2889
N.27	SUNSAT (Stellenbosch University Satellite)	2891
N.28	SURFSAT (Summer Undergraduate Research Fellowship Satellite)	2894
N.29	SwissCube	2895
N.30	TechSat/Gurwin-II	2905
N.31	TUBSAT (Technical University of Berlin Satellite)	2908
	N.31.1 TUBSAT-A	2908
	N.31.2 TUBSAT-B	2909
	N.31.3 TUBSAT-N (Technical University of Berlin Satellite-Nano)	2909
	N.31.4 DLR-TUBSAT	2911
	N.31.5 Maroc-TUBSAT	2913
N.32	UniSat-1 (University Satellite)	2914
	UniSat-2 (University Satellite-2)	2915
N.33	UniSat-3	2917
N.34	UWE-1 (Universität Würzburg's Experimentalsatellit-1)	2919
N.35	UWE-2 (University of Würzburg Experimentalsatellit-2)	2923
	Spacecraft:	2923
N.36	WeberSat	2928
N.37	CubeSat Program (A first attempt for a Picosatellite Standard)	2930
	N.37.1 AAUSat (Aalborg University CubeSat)	2932
	N.37.2 CanX-1 (Canadian Advanced Nanospace Experiments-1)	2933
	N.37.3 CUTE-I (Cubical TI-Tech Engineering satellite-I)	2934
	N.37.4 DTUSat (Technical University of Denmark Satellite)	2935
N.38	CUTE-1.7 (Cubical Tokyo Tech Engineering Satellite-1.7)	2936
	N.38.1 QuakeSat	2938
	N.38.2 XI (X-factor Investigator)	2939
Part O Reference Data and Definitions		2941
O.1	Definitions, Concepts, Summaries	2942
	O.1.1 Remote Sensing across the Electromagnetic Spectrum	2942
	O.1.2 Types and Classes of Remote Sensors and Sensing Data	2943
O.2	Some Aspects of Radiometric Instrument Calibration	2947
	O.2.1 GNSS Radio Occultation Sounding	2949
	O.2.2 Correction/Calibration Methods for Sensor Data	2951
	O.2.3 Electron-scanned Imaging Devices	2952
O.3	Scanners	2953
	O.3.1 Line Scanners	2953
	O.3.2 Electromechanical Line Scanner	2954
	O.3.3 Optoelectronic Scanners	2955
	O.3.4 Observation Schemes	2956

	O.3.4.1	Line (or linear) Detector Array	2957
	O.3.4.2	Area Arrays	2958
	O.3.4.3	PDA (Photodiode Array)	2959
	O.3.5	Staring Array Systems	2959
	O.3.6	Time Delay Integration (TDI)	2959
O.4		Sensor Detector Systems	2962
	O.4.1	Definitions	2962
	O.4.2	Charge-Transfer Devices	2972
	O.4.2.1	Charge-Coupled Device (CCD)	2973
	O.4.2.2	Charge-Injection Device (CID)	2976
	O.4.2.3	CMOS/APS Detectors	2977
	O.4.3	Infrared Radiation and Detection	2978
	O.4.3.1	Detector Arrays and Focal Plane Assemblies (FPAs)	2980
	O.4.3.2	Overview of spaceborne sensors with infrared bolometer detectors	2981
	O.4.3.3	UFPA (Uncooled Focal Plane Array) Infrared Detectors	2982
	O.4.3.4	Microbolometers	2983
	O.4.3.5	BST (Barium, Strontium and Titanate) Infrared Detectors	2984
	O.4.4	Radiation Detection Limits	2985
	O.4.5	Acousto-Optic Devices	2986
	O.4.6	Resolution (for Visible and Infrared Imagery)	2989
	O.4.7	SQUID Sensors in Magnetometry	2990
O.5		Cryocooling Techniques	2991
	O.5.1	Stirling Cycle Cooler	2991
	O.5.2	Pulse Tube Cooler	2992
	O.5.3	Hybrid Cryogenic System: CSE (Cryo System Experiment)	2992
	O.5.4	Optical Cooling	2993
O.6		Imaging Spectrometers	2994
	O.6.1	Imaging Fourier Transform Spectrometer (IFTS)	2996
	O.6.2	Spatially Modulated Interferometer Concept	2998
	O.6.3	Spatial Heterodyne Spectroscopy (SHS)	3002
O.7		Passive Radiometry (MW/MMW)	3004
	O.7.1	Radiometer Instruments	3007
	O.7.2	Aperture Synthesis in Radiometry	3010
O.8		Active Radiometry	3010
	O.8.1	Types of Radar Sensors	3011
	O.8.2	SAR Terminology and Definitions	3013
	O.8.3	SAR Imaging Modes	3015
	O.8.4	Phased Array Antenna Principle	3016
	O.8.5	Looks, Speckles and Radiometric Resolution of SAR Images	3017
	O.8.6	Lidars (Laser-Based Remote Sensing)	3017
	O.8.6.1	Backscatter Lidar	3017
	O.8.6.2	Differential Absorption Lidar (DIAL)	3018
	O.8.6.3	Raman Lidar	3018
	O.8.6.4	Doppler Wind Lidar (DWL)	3018
	O.8.6.5	Ranging and Altimeter Lidar	3019
	O.8.6.6	Lidar Principle	3020
O.9		Interferometry	3022
	O.9.1	Radar Interferometry	3025
	O.9.2	VLBI (Very Long Baseline Interferometry)	3027
	O.9.3	Nulling Interferometry	3028
O.10		Orbital Concepts and Terminology in Remote Sensing	3029
	O.10.1	Sun-synchronous Orbit (SSO)	3031
	O.10.2	Geosynchronous Orbit	3032

O.10.3	Repeat Coverage or Temporal Resolution	3034
O.10.4	LEO (Low Earth Orbit)	3035
O.10.5	MEO (Medium Earth Orbit)	3036
O.10.6	HEO (Highly-Elliptical Earth Orbit)	3036
O.10.7	EEO (Elliptical Earth Orbit)	3037
O.10.8	Bistatic Orbits for Spaceborne SAR Interferometry	3037
	O.10.8.1 The Interferometric Cartwheel Configuration	3037
	O.10.8.2 Cross-track Pendulum	3041
	O.10.8.3 Combi Orbit Configuration (Cartwheel+Pendulum)	3042
O.10.9	Some Orbit Selection Requirements	3042
O.10.10	Walker Constellation	3042
O.10.11	Libration Points/Lagrange Points	3043
O.11	Observational Scales in Modeling	3046
O.12	On-Orbit Electric Propulsion	3049
	O.12.1 Basic Thruster Concepts	3050
	O.12.1.1 Specific Impulse (Isp)	3050
	O.12.1.2 Electrothermal thrusters	3050
	O.12.1.3 Electrostatic thrusters	3051
	O.12.1.4 Electromagnetic thrusters	3052
	O.12.2 Some Developed Thruster Systems	3053
O.13	On-board Payload Concepts and Technologies	3060
	O.13.1 Conventional on-board systems	3060
	O.13.2 Introduction of on-board payload processing functions	3061
	O.13.3 Advanced payload data systems	3066
	O.13.4 On-board networks	3067
O.14	Summary of World Data Centers (WDCs)	3069
O.15	Committee on Earth Observation Satellites - CEOS	3072
O.16	Space Shuttle Mission Chronology	3074
O.17	Solar Wind and the Magnetosphere - An Introduction	3079
O.18	Frequency Designations	3083
Appendix A Glossary		3087
Appendix B Acronyms and Abbreviations		3203
	Units of Measure and some Physical Constants	3203
	General conventions of unit representations:	3207
Appendix C Index of Sensors		3335
Part P Survey of Airborne Sensors		3373
P.1	AAHIS (Advanced Airborne Hyperspectral Imaging Spectrometer)	3375
P.2	AAMAS (Aircraft-borne Automatic Mass Spectrometer)	3376
	P.2.1 TQMS (Triple Quadrupole Mass Spectrometer)	3377
P.3	ADS40 (Airborne Digital Sensor 40)	3378
P.4	Aerosol Experiment	3380
P.5	AeS-1 (Aerosensing-1)	3380
P.6	AES (Airborne Emission Spectrometer)	3382
P.7	AHSTRA (Airborne Heterodyne Spectrometer THz Astronomy)	3382
P.8	AIMR (Airborne Imaging Microwave Radiometer)	3383
P.9	AIMS-1000 (Airborne Imaging Mapping and Surveillance System)	3384
P.10	AirCam	3384
P.11	AIRDAS (Airborne Disaster Assessment System)	3385
P.12	AirMISR (Airborne Multi-angle Imaging SpectroRadiometer)	3386

P.13	AIRSAR (Airborne SAR)	3387
	P.13.1 TOPSAR (Interferometric Radar Topographic Mapping Instrument)	3389
P.14	AIS (Airborne Imaging Spectrometer)	3391
P.15	AISA (Airborne Imaging Spectrometer for different Applications)	3391
P.16	ALAS (Airborne Laser Altimeter System)	3393
P.17	ALF (Airborne Laser Fluorosensor)	3394
P.18	ALIAS (Aircraft Laser Infrared Absorption Spectrometer)	3396
	P.18.1 ALIAS-I on ER-2 Aircraft	3396
	P.18.2 ALIAS-II on Perseus Aircraft	3396
P.19	ALPS (Airborne Laser Polarization Sensor)	3397
P.20	ALTM (Airborne Laser Terrain Mapping)	3398
P.21	AMMR (Airborne Multichannel Microwave Radiometer)	3399
P.22	AMMS (Airborne Microwave Moisture Sounder)	3399
P.23	AMPR (Advanced Microwave Precipitation Radiometer)	3399
P.24	AMPS (Airborne Multisensor Pod System)	3400
	P.24.1 Sony DXC-750 3-CCD Video Camera	3401
	P.24.2 Wild RC30 Large Format Camera	3401
	P.24.3 AGEMA Thermal Imager	3402
	P.24.4 Sandia SAR	3402
	P.24.5 COHU 5560 Low Light Camera	3403
	P.24.6 CASI (Compact Airborne Spectrographic Imager)	3403
	P.24.7 AMS (Airborne Multispectral Scanner)	3403
	P.24.8 EGS (Echelle Grating Spectrometer)	3403
	P.24.9 AC-ITMS (Air Concentrator-Ion Trap Mass Spectrometer)	3404
	P.24.10 TTS (Target Tracking System)	3404
	P.24.11 AKS (Aerial Krypton Sampler)	3404
	P.24.12 R-TARAC (Real-Time Airborne Radionuclide Analyzer and Collector) ...	3405
P.25	AMSOS (Airborne Millimeter & Submillimeter-wave Observing System)	3405
P.26	AMSS MK-II (Airborne Multi-Spectral Scanner)	3406
P.27	AOL (Airborne Oceanographic Lidar)	3407
P.28	APDOR-95 (Airborne Polarimetric Doppler Radar)	3407
P.29	APE (Airborne Polar Experiment)	3408
	P.29.1 SAFIRE-A (Spectroscopy of the Atmosphere w. FIR Emission - Airborne)	3409
	P.29.2 ARIAS (Airborne Remote-Sensing & In-Situ Aerosol Measuring System)	3410
	P.29.3 GASCOD (Gas Absorption Spectrometer Correlating Optical Differences)	3412
	P.29.4 ABLE (Airborne Lidar Experiment)	3412
	P.29.5 MAL (Micro-Joule Airborne Lidar)	3413
	P.29.6 ECOC (Electrochemical Ozone Cell)	3414
	P.29.7 FLASH (Fluorescent Airborne Stratospheric Hygrometer)	3414
	P.29.8 ACH (Aircraft Condensation Hygrometer)	3415
	P.29.9 ACAP (Airborne Counter of Aerosol Particles)	3416
	P.29.10 FOZAN (Fast Ozone Analyzer)	3416
	P.29.11 COPAS (Condensation Particle Detection System)	3417
P.30	APEX (Airborne PRISM Experiment)	3418
P.31	APMIR (Airborne Polarimetric Microwave Imaging Radiometer)	3420
P.32	ARES (Airborne Remote Earth Sensing)	3421
P.33	ARGUS (Two-Channel Atmospheric Tracer Instrument)	3424
P.34	ARL (Airborne Raman Lidar)	3426
P.35	ARMAR (Airborne Rain Mapping Radar)	3427
P.36	ASAS (Advanced Solid-State Array Spectroradiometer)	3428
P.37	ASIRAS (Airborne SAR/Interferometric Radar System)	3429
P.38	ATHOS (Airborne Tropospheric Hydrogen Oxide Sensor)	3438
P.39	ATLAS (Airborne Tunable Laser Absorption Spectrometer)	3439
P.40	ATLAS (Airborne Terrestrial Applications Scanner)	3440
P.41	Atmospheric Measurements on Commercial Airline Flights	3442

P.41.1	MOZAIC (Measurement of Ozone by Airbus In-Service Aircraft)	3442
P.41.2	ACORN	3443
P.41.3	CARIBIC	3444
P.41.4	ASE (Automatic Air-Sampling Equipment)	3446
P.42	ATSS (Airborne Terrain Survey System)	3448
P.42.1	ScaLARS-2 (Scanning Laser Altitude and Reflectance Sensor)	3449
P.43	AVIRIS (Airborne Visible/Infrared Imaging Spectrometer)	3450
P.44	AWI Sensors	3453
P.44.1	PS100EL Laser Altimeter	3454
P.44.2	AWSR (Airborne Water Substance Radiometer)	3454
P.45	B-Flux (Boundary-Layer Flux System)	3455
P.46	CAESAR	3458
P.47	CALS (Cloud and Aerosol Lidar System)	3459
P.48	CAMS (Calibrated Airborne Multispectral Scanner)	3460
P.49	CAR (Cloud Absorption Radiometer)	3460
P.50	CARABAS (Coherent All Radio Band Sensing)	3462
P.51	CASI (Compact Airborne Spectrographic Imager)	3465
P.52	CASI-2 (Compact Airborne Spectrographic Imager - 2)	3466
P.53	Cast Eyes	3467
P.54	Chinese Airborne Instruments	3469
P.54.1	CIS (Chinese Imaging Spectrometer)	3469
P.54.2	AMS (Airborne Multispectral Scanner)	3470
P.54.3	TIMS (Thermal Imaging Multispectral Scanner)	3470
P.54.4	Prototype Scanner	3470
P.54.5	MAIS (Modular Airborne Imaging Spectrometer)	3470
P.54.6	CASSAR (Chinese Academy of Sciences SAR)	3471
P.55	CHOPPY (Chopped Pyrgeometer)	3472
P.56	CHRISS (Compact High Resolution Imaging Spectrograph Sensor)	3473
P.57	CNC (Condensation Nucleus Counter)	3474
P.58	CRL Radar/Radiometer	3475
P.59	C-SCAT (C-band Scatterometer)	3476
P.60	C-STAR (Conically-Scanning Two-Look Airborne Radiometer)	3477
P.61	CVI (Counterflow Virtual Impactor)	3478
P.62	C/X-SAR	3478
P.63	D2P (Delay-Doppler Phase-monopulse Radar)	3481
P.64	Daedalus Instruments (Digital Multispectral Scanner)	3482
P.64.1	ATM (Airborne Thematic Mapper)	3482
P.64.2	Analog Bispectral Instruments	3484
P.64.3	Analog and Digital Bispectral/Multispectral Instruments	3486
P.64.4	AOCI (Airborne Ocean Color Imager Spectrometer)	3487
P.64.5	AMS (Airborne Multispectral Scanner)	3488
P.64.6	TIMS (Thermal Infrared Multispectral Scanner)	3489
P.64.7	Wildfire	3490
P.64.8	MIVIS (Multispectral Infrared and Visible Spectrometer)	3490
P.64.9	MAS (MODIS Airborne Simulator)	3491
P.64.10	AHS (Airborne Hyperspectral Scanner)	3492
P.64.11	ADC (Airborne Digital Camera)	3493
P.65	DARMS (Digital Aerial Right-of-Way Monitoring System)	3494
P.66	Deimos	3494
P.67	DLR Lidar Instruments	3495
P.68	DMSV (Digital Multi-Spectral Video)	3498
P.69	DOAS (Differential Optical Absorption Spectroscopy)	3499
P.70	DOE Airborne Instruments in ARM Program	3499
P.70.1	MPIR (Multispectral Pushbroom Imaging Radiometer)	3500
P.70.2	CDL (Cloud Detection Lidar)	3500

P.70.3	HONER (Hemispherical Optimized Net-flux Radiometer)	3501
P.70.4	UAV-AERI (UAV Atmospheric Emitted Radiance Interferometer)	3502
P.71	DO-SAR (Dornier SAR)	3502
P.72	DPA (Digital Photogrammetric Assembly)	3504
P.73	DRA-SAR (Defense Research Agency SAR)	3505
P.74	Dual Polarized 37 GHz Radiometer	3507
P.75	DUTSCAT (DUT Airborne Radar Scatterometer)	3508
P.76	EDOP (ER-2 Doppler Radar)	3508
P.77	ELDORA/ASTRAIA	3510
P.78	EMIRAD (Electromagnetics Institute Radiometer)	3512
P.79	EMISAR (Electromagnetics Institute SAR)	3513
P.80	EOS (Opto-Electronic Scanner)	3514
P.81	ER-2 High-Altitude Aircraft Program	3515
P.82	ERASME (Etude Radar des Sols et des Mers)	3517
P.83	ERIM Airborne Instruments	3518
P.83.1	M-5 (Michigan-5 Imager)	3518
P.83.2	M-7 (Mapper Multispectral Testbed)	3519
P.83.3	P-3/SAR (ERIM/Navy Sensor)	3522
P.83.4	DCS (Data Collection System)	3524
P.83.5	IFSARE (Interferometric SAR for digital terrain elevation data)	3526
P.84	EROS Digital Imagery and Photographic Products	3528
P.84.1	Airborne Science and Applications Program (ASAP)	3529
P.85	E-SAR (Experimental SAR)	3529
P.86	E-SLAR (Experimental Side-Looking Airborne Radar)	3530
P.87	ESMR (Electronically Scanned Microwave Radiometer)	3531
P.88	ESTAR (Electronically Steered Thinned Array Radiometer)	3532
P.89	FAST	3534
P.90	FIRS-2 (Far Infrared Spectrometer)	3534
P.91	FIRSC (Far Infrared Sensor for Cirrus)	3536
P.92	FIRST (Far–Infrared Spectroscopy of the Troposphere)	3537
P.93	FISH (Fast In-Situ Stratospheric Hygrometer)	3548
P.94	FLASH (FOA Laser Airborne Sounder for Hydrography)	3549
P.95	FLI (Fluorescence Line Imager)	3549
P.96	FOLPEN (Foliage Penetration VHF Impulse SAR)	3550
P.96.1	GPR (Ground Penetrating Radar)	3551
P.97	FTVHSI (Fourier Transform Visible Hyperspectral Imager)	3551
P.98	Geophysika M-55 Stratospheric Aircraft	3552
P.99	GER Corporation Instruments	3553
P.99.1	AAS (Airborne ASTER Simulator)	3553
P.99.2	DAIS-2815 (Digital Airborne Imaging Spectrometer)	3554
P.99.3	DAIS-7915 (Digital Airborne Imaging Spectrometer)	3555
P.99.4	DAIS-16115 (Digital Airborne Imaging Spectrometer)	3556
P.99.5	GER-63 Channel Scanner	3556
P.99.6	DAIS-3715 (Digital Airborne Imaging Spectrometer)	3557
P.100	GIFS (Geostationary Imaging Fabry–Perot Spectrometer)	3557
P.101	GRASS (Gonio Radiometric Spectrometer System)	3566
P.102	Harvard Atmospheric Chemistry Instruments	3571
P.102.1	OH/HO ₂ Instrument	3571
P.102.2	ClO/BrO Instrument	3572
P.102.3	H ₂ O Instrument	3572
P.102.4	O ₃ Instrument	3573
P.102.5	ClONO ₂ Instrument	3573
P.102.6	NO/NO _y Instrument	3573
P.102.7	CO ₂ Instrument	3574
P.103	HELISCAT (Helicopter Scatterometer)	3574

P.104 HIS (High-Resolution Interferometer Sounder)	3575
P.105 HIWRAP (High–Altitude Imaging Wind and Rain Airborne Profiler)	3577
P.106 HRSC (High-Resolution Stereo Camera)	3587
P.106.1 HRSC-A (High-Resolution Stereo Camera - Airborne)	3588
P.106.2 HRSC-A/ (High-Resolution Stereo Camera - Airborne/)	3589
P.107 HUT (Helsinki University of Technology) Instruments	3589
P.107.1 HUTRAD (Helsinki University of Technology Radiometer)	3590
P.107.1.1 Nonimaging Subsystem of HUTRAD	3590
P.107.1.2 Imaging Subsystem of HUTRAD	3591
P.107.2 HUTSCAT (Helsinki University of Technology Scatterometer)	3591
P.107.3 HUTSLAR (HUT Side-Looking Airborne Radar)	3592
P.107.4 MINISCAT	3593
P.108 HYDICE (Hyperspectral Digital Imagery Collection Experiment)	3594
P.109 HyMap (Hyperspectral Mapper)	3596
P.110 IFSAR (Interferometric SAR)	3597
P.111 IKI RAN Airborne Sensors	3599
P.111.1 NIT (Side-looking Airborne Real Aperture Radar)	3599
P.111.2 MKF-6 (Multispectral Camera)	3599
P.111.3 NAMR (Nadir-looking Airborne Multichannel Radiometer)	3600
P.111.4 Delta-K Spectrometer	3600
P.111.5 IKIRAD (IKI Radiometer)	3600
P.111.6 K-band Dual-frequency Atmospheric Radiometer	3601
P.111.7 Multipolarization K- and Ka-band Polarimeters	3601
P.112 INGARA (Australian Airborne Imaging Radar System)	3602
P.113 ISM (Infrared Imaging Spectrometer)	3603
P.114 Japanese Airborne Sensors in the TRMM/ADEOS-II Programs	3604
P.114.1 AMR (Airborne Microwave Radiometer)	3604
P.114.2 AMSS (Advanced MultiSpectral Scanner)	3605
P.114.3 CAMPR (CRL Airborne Multiparameter Precipitation Radar)	3606
P.115 LAC (Large Area Collector)	3607
P.116 LARSEN (Airborne Scanning Lidar)	3608
P.117 LASAL (Large Aperture Scanning Airborne Lidar)	3608
P.118 LASE (Lidar Atmospheric Sensing Experiment)	3609
P.119 LEAF (Laser Environmental Airborne Fluorosensor)	3610
P.120 LEANDRE	3611
P.121 LFS (Laser Fluorosensor)	3612
P.122 Leica RC30 (Aerial Camera System)	3614
P.123 LIP (Lightning Instrument Package)	3615
P.124 LVIS (Laser Vegetation Imaging Sensor)	3616
P.125 MACAWS (Multi-Center Airborne Coherent Atmospheric Wind Sensor)	3618
P.126 MAMS (Multispectral Atmospheric Mapping Sensor)	3619
P.127 MARA (Multimode Airborne Radar Altimeter)	3620
P.128 MARSCHALS (Millimeter–Wave Airborne Receiver for Spectroscopic Characterization of Atmospheric Limb Sounding)	3622
P.129 MARSS (Microwave Airborne Radiometer Scanning System)	3629
P.130 MASP (Multiangle Aerosol Spectrometer Probe)	3630
P.131 MASTER (MODIS/ASTER Airborne Simulator)	3631
P.132 MCR (Multispectral Cloud Radiometer)	3633
P.133 MEIS (Multi-detector Electro-optical Imaging Sensor)	3634
P.134 MERES (Multifrequency Radiometer for Remote Sensing of the Sea Surface)	3635
P.135 MIPAS (Michelson Interferometer for Passive Atmospheric Sounding)	3636
P.135.1 MIPAS-LM (Laboratory Model)	3637
P.135.2 MIPAS-B (MIPAS Balloon)	3637
P.135.3 MIPAS-B2	3638
P.135.4 MIPAS-FT (Flugzeug Transall)	3639

P.136	MIR (Millimeter-Wave Imaging Radiometer)	3640
P.137	MIRACO2LAS (Mid-IR Airborne CO2 Laser Spectrometer)	3640
P.138	MIRAS (Microwave Imaging Radiometer with Aperture Synthesis)	3641
P.139	MIROR (Michelson Interferometer with Rotating Retroreflector)	3643
P.140	MISI (Modular Imaging Spectrometer Instrument)	3645
P.141	MITE (Megapixel Imaging Technology Camera System)	3646
P.142	MkIV (Mark-IV Interferometer)	3647
P.143	MMS (Meteorological Measurement System)	3648
P.144	MMW-SAR (Millimeter Wave SAR)	3649
P.145	MOBY (Marine Optical Buoy)	3651
P.146	MSS-5000 (Maritime Surveillance System)	3652
P.146.1	SLAR (Side-Looking Airborne Radar)	3653
P.146.2	IR/UV (Infrared/Ultraviolet System)	3653
P.146.3	MWR (Scanning Microwave Radiometer)	3653
P.146.4	Camera (Photographic Camera System)	3654
P.146.5	Video (Video Camera System)	3654
P.146.6	THERMO (Thermal Radiometer)	3654
P.147	MSS (Multispectral Scanner)	3654
P.148	MTP (Microwave Temperature Profiler)	3655
P.149	MTS (Millimeter-Wave Temperature Sounder)	3656
P.150	MUSIC (Multi-Spectral Infrared Camera)	3657
P.151	NAILS (NCAR Airborne Infrared Lidar System)	3658
P.152	NAPP (National Aerial Photography Program)	3659
P.153	NASAR-1 (NASDA Airborne SAR-1)	3660
P.154	NASIC (NASA Aircraft - Satellite Instrument Calibrator)	3660
P.155	NAST (NPOESS Aircraft Sounder Testbed)	3662
P.155.1	NAST-I (NPOESS Aircraft Sounder Testbed - Interferometer)	3663
P.155.2	NAST-M (NPOESS Aircraft Sounder Testbed - Microwave Sounder)	3664
P.156	NCARNOX (NCAR NOx Chemiluminescent Sensor)	3666
P.157	NCAR Electra Aircraft Instrumentation	3666
P.158	NEC-SAR (NEC Corporation SAR)	3667
P.159	NOAA/AOC Airborne Program	3669
P.159.1	NOAA WP-3D Doppler Radar System	3671
P.159.2	Scan Strategies of TDR	3672
P.159.3	ASDL (NOAA Aircraft Satellite Data Link)	3674
P.159.4	ODW (Omega Dropwind Sonde)	3675
P.159.5	NOAA P-3 Infrared Radiometers	3675
P.159.6	AXBT (Air Expendable Bathythermograph)	3676
P.160	NOAL (NOAA Ozone Airborne Lidar)	3676
P.161	NPL Instruments	3677
P.161.1	FTS (Fourier Transform Spectrometer)	3677
P.161.2	TDLHS (Tunable Diode Laser Heterodyne Spectrometer)	3678
P.162	NS001 (Thematic Mapper Simulator)	3679
P.163	NUSCAT (Airborne Ku-band Scatterometer)	3679
P.164	OLS (Oceanographic Lidar System)	3681
P.165	OVID (Optical Visible and Near-Infrared Detector)	3681
P.166	PAMIR (Phased Array Multifunctional Imaging Radar)	3682
P.167	PBMR (Pushbroom Microwave Radiometer)	3684
P.168	PERSEUS (Unmanned High-Altitude Research Aircraft)	3685
P.169	PHARUS (PHased ARray Universal SAR)	3687
P.170	PI-SAR (Polarimetric and Interferometric - SAR)	3689
P.171	PMS (Particle Measuring Systems Inc.) Instruments	3690
P.172	PMS (Portable Multichannel Spectrometer)	3692
P.173	POLDER (Airborne Instrument)	3694
P.174	PORTOS	3696
P.175	PRIRODA Airborne Instruments	3696

P.176 PSR (Polarimetric Scanning Radiometer)	3698
P.177 RACS (Rotating Antenna C-band Scatterometer)	3700
P.178 Radius (Microwave Radiometer)	3701
P.179 RAMS (RAdiation Measurement System)	3702
P.180 RAMSES (Radar Aéroporté Multi-Spectral d'Etude des Signatures)	3703
P.181 RENE	3704
P.182 RESSAC (Radar pour l'Etude du Spectre des Surfaces par Analyse Circulaire) ...	3705
P.183 RMK (Reihenmeßkammer - Metric Camera)	3707
P.184 ROSIS (Reflective Optics System Imaging Spectrometer)	3708
P.185 ROWS (Radar Ocean Wave Spectrometer)	3708
P.186 R-SLAR (RRL-SLAR)	3710
P.187 SABL (Scanning Aerosol Backscatter Lidar)	3710
P.188 SASAR (South African SAR)	3711
P.189 SB-RAS Airborne Instruments	3713
P.189.1 MAKREL-2 Lidar	3713
P.189.2 Svetozar-3 Lidar	3714
P.189.3 M2M (Makrel-2 Modified)	3715
P.190 SFSI (SWIR Full Spectrographic Imager)	3715
P.191 SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey)	3716
P.192 SILVACAM (Real-time False Color CCD Video Camera)	3718
P.193 SLAR (Side-Looking Airborne Radar, NLR)	3719
P.194 SMIFTS (Spatially Modulated Imaging FTS)	3720
P.195 SOFIA (Stratospheric Observatory for Infrared Astronomy)	3723
P.195.1 Payload/Instrument Complement	3723
P.195.2 Complement of German Science Instruments	3727
P.195.3 Complement of US Science Instruments	3729
P.196 Spectra-View	3734
P.197 SRI Lidar Systems	3735
P.197.1 ALPHA-1, -2 (Airborne Lidar Plume and Haze Analyzer)	3735
P.197.2 RFUV (Raman, Fluorescent and UV-DIAL Lidar)	3737
P.198 SSTR (Sea Surface Temperature Radiometer)	3738
P.199 STAR (Sea-Ice and Terrain Assessment Radar)	3738
P.199.1 Star-1 and Star-2	3738
P.199.2 STAR-3i	3740
P.200 SUMAS/ASUR/RAL-Sensor (Submillimeter Radiometers)	3742
P.201 Sunphotometer	3744
P.201.1 HIRAASS (High Resolution Airborne Autotracking Sun Spectrometer) ..	3744
P.202 THOMAS (THz OH Measurement Airborne Sounder)	3745
P.203 TOPOSYS (Scanning Laser System)	3745
P.204 TRWIS (TRW Imaging Spectrometer)	3746
P.205 TSCC (Tilt Scan CCD Camera)	3747
P.206 TU-134A (Tupolev Flying Laboratory)	3748
P.206.1 SIR (Scanning Infrared Radiometer)	3748
P.206.2 IMARC (Imaging Multifrequency Airborne Radar Complex)	3748
P.206.3 AFA-41/10 (Aerial Foto Apparatus)	3750
P.207 TWiLiTE (Tropospheric Wind Lidar Technology Experiment)	3750
P.208 UMMCI	3755
P.209 VIFIS (Variable Interference Filter Imaging Spectrometer)	3756
P.210 VIRL (Visible and near Infrared Lidar)	3758
P.211 VIS (Video Imaging System)	3760
P.212 WAOSS (Wide-Angle Optoelectronic Stereo Scanner)	3761
P.212.1 WAOSS (Spaceborne Version)	3761
P.212.2 WAOSS (Airborne Version)	3761
P.212.3 WAAC (Wide-Angle Airborne Camera)	3762
P.213 WHiRL (Wide-angle High-Resolution Line-imager)	3762
P.214 WINDRAD (Wind Radiometer)	3763

P.215 WIS (Wedge Imaging Spectrometer) 3763

Part Q Survey of Campaigns 3771

Q.1 Campaigns 3772

Q.2 International Research Programs 3852

 Q.2.1 International Geosphere-Biosphere Program 3853

 Q.2.2 World Climate Program 3855