

# Table of Contents

Foreword and Acknowledgements .....	1
<b>1 Earth Observation History on Technology Introduction .....</b>	<b>7</b>
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

<b>Part A</b>	<b>Atmosphere/Radiation/Aeronomy Missions</b>	<b>775</b>
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
<b>Part B</b>	<b>Commercial Imaging Satellites</b>	<b>909</b>
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
<b>Part C Data Collection (Messaging) Systems .....</b>		<b>985</b>
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
<b>Part D Earth Observation/Monitoring Missions .....</b>		<b>1015</b>
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
<b>Part E Atmosphere/Radiation/Aeronomy Missions</b>		<b>1471</b>
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-IK	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
<b>Part H Satellite Radionavigation Systems .....</b>		<b>1783</b>
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
<b>Part I Satellite Event, Emergency &amp; Environmental Monitoring ...</b>		<b>1865</b>
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
 <b>Part J Shuttle - Selected Missions and Payloads .....</b>		<b>1949</b>
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
<b>Part L Space Stations .....</b>		<b>2267</b>
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
<b>Part M Technology Missions . . . . .</b>		<b>2319</b>
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
<b>Part N University/Student-Developed Satellites &amp; Payloads .....</b>	<b>2793</b>
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
<b>Part O Reference Data and Definitions</b>		<b>2941</b>
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
<b>Appendix A Glossary . . . . .</b>		<b>3087</b>
<b>Appendix B Acronyms and Abbreviations . . . . .</b>		<b>3203</b>
	Units of Measure and some Physical Constants . . . . .	3203
	General conventions of unit representations: . . . . .	3207
<b>Appendix C Index of Sensors . . . . .</b>		<b>3335</b>
<b>Part P Survey of Airborne Sensors . . . . .</b>		<b>3373</b>
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 <sub>2</sub> Instrument .....	3571
P.102.2	ClO/BrO Instrument .....	3572
P.102.3	H <sub>2</sub> O Instrument .....	3572
P.102.4	O <sub>3</sub> Instrument .....	3573
P.102.5	ClONO <sub>2</sub> Instrument .....	3573
P.102.6	NO/NO <sub>y</sub> Instrument .....	3573
P.102.7	CO <sub>2</sub> 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