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A

和平利用外层空间委员会

在科学和技术小组委员会第三十三届会议上提出的科学和技术情况介绍

秘书处的报告

1. 在科学和技术小组委员会第三十三届会议期间，国际科学联合国会理事会(科学理事会)空间研究委员会(空间研委会)和国际宇宙航行联合会(宇航联合会)协同各会员国举办了“利用微型和小型卫星发展低成本空间活动，同时考虑到发展中国家的需要”的专题讨论会，以补充小组委员会范围内就这一主题进行的讨论。专题讨论会是根据小组委员会第三十二届会议的建议(A/AC.105/605，第136段)举办的，该建议后来得到和平利用外层空间委员会第三十八届会议[1]和大会1995年12月6日第50/27号决议核可。

2. 这是空间研委会和宇航联合会在科学和技术小组委员会年会期间举行的第十个专题讨论会，每年讨论的专题是由小组委员会在前一届会议上选定的。专题讨论会继小组委员会届会第一周内下午会议的辩论完毕后于1996年2月12日和13日分两部分举行。

3. 除了空间研委会和宇航联合会应小组委员会要求而举行的专题介绍外，会员国代表团还结合小组委员会议程的一些项目安排了由空间科学和应用专家主讲的一些科学和技术情况介绍。一些国家组织和国际组织也介绍了自己所进行的科学技术活动。

4. 为使他们更广泛地了解专题讨论会和其他专题介绍所提供的关于空间科学、技术和应用的最新情况，秘书处编写了下述资料提要。

5. 附件中载有对科学和技术小组委员会第三十三届会议期间所作科学和技术专题介绍的更详细的情况。附件仅为英文。专题介绍和讲演人一览表载于附件的附录中。

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一. 专题介绍提要

利用微型和小型卫星发展低成本的空间活动，同时考虑到发展中国家的特殊需要

6. 据指出，在多数发展中国家，至少可以看出对小型和微型系统的两类需要。第一类可称为直接需要，与可通过各种空间技术的应用加以解决的社会和经济问题有关。第二类需要带有间接性，涉及争取条件充分利用本国投资取得空间系统和服务。

7. 低地轨道通信系统的使用可以有许多服务；最有趣的方面之一是便携终端和现有固定电信网普通电话之间的通信。在这种情况下，两个用户可位于领土上任何地方，特别是在边远地方或缺乏通信基础设施的地区。在两个流动用户之间以及一个流动用户与全球任何地方固定网络系统用户之间进行通信也是有可能的。

8. 配合低地轨道通信的双向特点利用自动数据收集平台，可安装覆盖面广并能提供实时服务的数据收集网。此外，低地轨道通信系统还可以范围为100 米的精确度确定任何流动终端用户的位置。低地轨道通信流动终端还可配合传真机传送图象数据。因此，它可使用户在边远地区医疗紧急情况下发送心电图传真等。

9. 远程医疗是可提高医疗服务的效率的一种应用，它可以将使用廉价而简单的传感器获得的数据直接传送至大型医疗中心中复杂的处理机中由专门医生进行判读。这样便可将强大而有效紧急服务送至贫困的不发达地区，拯救许多人的生命和免除不必要的运送病人的麻烦。保健卫星项目是远程医疗应用的一个很好的例子：它使用一个60 公斤的低地轨道卫星在尼日利亚与北美之间转发医疗数据资料。流动通信在发生自然灾害时也可发挥重要作用，可使援助更早地到达灾害受害者手中，并可为救助组提供后勤支助。

10. 许多发展中国家很早就能利用卫星遥感的种种好处，但要最大限度地发挥现有能力的好处却还有很多工作要做。不过国家和区域一级也存在着一种需要找出新的解决办法的独特需要。例如巴西和大韩民国便正在开发解决自己具体需要的新的卫星方案。拉丁美洲、东南亚和其他区域的发展中国家需要有诸如频谱带、空间分辨率、时间分辨率、图象成本、地面设备投资水平和利用所需的专门知识等特别传感器参数。

11. 合作空间活动往往也得到某种技术转让的支助。开发小型卫星项目方面成功的技术转让意味着一个由开发组取得为生产下一代小型卫星所需的充分的动力的过程。实现技术转让的途径有好几个，但成功的转让应当是知识转让而不是技术一揽子转让（原理及专门知识转让）。对发展中国家进行小型卫星设计、生产和经营方面培训的方案的例子很多。例如，大不列颠及北爱尔兰联合王国的萨里大学便向智利、巴基斯坦和大韩民国甚至决定开展空间方案的欧洲小国提供低于100公里的小型卫星开发方面的这类援助。

12. 阿根廷的一个小卫星项目科学应用卫星－ B 号正处于同美国（飞马号发射装置）合作预备阶段。项目的主要目标是设计一个带有科研有效载荷的卫星，以推动太阳物理学和天体物理学的研究。卫星重180公斤，预期最低活动寿命为三年。卫星计划于1996年发射。正在预备在1999至2006年发射用于科研和遥感的新一代卫星，科学应用卫星－C号和科学应用卫星－D号。

13. 巴西对从利用空间技术的边远平台收集数据极为重视。 1993年2月，随着 Coleta de Dados （ SCD 1 ）号卫星的发射，成功地开始了巴西全面空间飞行任务（ MECB ）。这颗卫星已经超过预期使用寿命两年，但仍在运作。为了确保飞行任务的持续进行，将至少发射两颗类似的卫星。另外，在这次飞行任务中还将使用经改进的 SCD 3 号卫星（ 200 公斤）， 以展示赤道地区有声通讯和数据通讯的设想。

14. 智利的第一颗投入运营的卫星将是与萨里大学（联合王国）合作研制的 FASat － Bravo 号卫星。这颗46公斤重的微型卫星将于 1996年8月射入环形轨道650公里之处，倾角为82.5°。这颗卫星将进行臭氧层监测实验、数据传送实验、实验性地球成像系统及其他设备，包括一项教育方面的实验。通过利用卫星提供的通信联接，学生将能够进行研究活动（轨道力学、卫星通信分析、遥测分析等等），每月1至2两天。

15. 韩国科学和技术高级研究所卫星研究中心（ KAIST ）开始了发展空间技术的方案，分别于 1992 年和 1993 年发射了两颗科学和实验微型卫星，KITSAT 1 号和 2 号。目前该研究中心正在设计新的本国制造的 KITSAT 3 号卫星，以便提高前两颗微型卫星的能力。该方案的一个主要目标是发展一种具有极为精确的高度控制能力、高速数据传递能力和为韩国空间工业和研究机构提供实际经验的微型卫星系统。 KITSAT 3号卫星的遥感有效载荷将能够监测亚洲和太平洋地区发生的诸如洪水、火山爆发和地震等对环境造成损害的灾难。

16. 在南非， SUNSAT 微型卫星项目确立于 1992 年，目的是为了增加研究生工程设计的机会，促进与斯泰伦博西大学的国际交流。这颗 60 公斤的微型卫星将能够提供全球耕地、自然植被和污染的图象。这颗卫星还可作为电子信箱，围绕地球飞行，接收和发送电文以及对学校的讲演和数据中转实验。 SUNSAT 应由美国的德尔塔发射器于 1997 年 3 月与丹麦的磁层研究卫星 Oersted 一道发射进入极轨道，高度为 450 至 850 公里。 SUNSAT 还将携带美国国家航空和航天局（美国航天局）的全球定位系统导航接收器以及一套用于精确定位实验的激光反射器。

17. 西班牙的一个空间项目 MINISAT 由西班牙科学和技术部门间委员会（ CICYT ）于 1992 年交给设在马德里的国家航天航空技术研究所。从 1996 年开始，飞马座号机载发射器发射质量为 180 至 500 公斤的组合式卫星（重量多少取决于所用的组件数目）。第一颗卫星 MINISAT 01 号将包括基础平台，用于科学研究。 MINISAT 1 号卫星将是一颗改良的卫星，装有遥感观测设备； MINISAT 2 号将利用基础平台提供远距离通信，甚至从地球静止轨道提供。

18. 1995 年 8 月 3 日发射了一颗小型科研亚卫星 MAGION 4 号，同时发射的还有 INTERBALL 1 号“母”卫星。 MAGION 4 号卫星在进入预计轨道（远地点 191,907 公里；近地点 193 公里；倾角 63.0°）后脱离母卫星。这颗卫星质量为 60 公斤，是与大气物理研究所（捷克共和国）、格拉茨技术大学（奥地利）以及空间研究所（俄罗斯联邦）共同合作研制的。该卫星的科研有效载荷的目的是为了在 INTERBALL 空间项目的框架内研究电离层电波现象和等离子体参照系数。相距不远的两颗卫星同时进行测量，可得到所观察到的现象的时间及空间分辨率。

19. 中欧高级研究卫星（ CESAR ）是准备于 1998 年发射的一颗大约 300 公斤重的航天器，该航天器将在近地点为 400 公里，远地点为 1000 公里以及倾角为 70° 的轨道上飞行。这次科研飞行将与磁层、电离层和热层环境的研究有关。这一由意大利空间局（意空局）制造的航天器将携带分别由奥地利、捷克共和国、匈牙利、波兰和斯洛伐克科学家提供的十项不同的实验。

20. 1993 年年底，法国国家空间研究中心成立了一个小型卫星工作组，负责就研制对法国地球观测实验卫星系统进行补充的一系列小型卫星提出建议，每项飞行任务的费用应不超过 3 亿法国法郎，研制时间为两年。建议的方案名称为 Plateforme reconfigurable pour l’observation, les télécommunications

et les usages scientifiques（PROTEUS）。预计将于1999年进行第一次飞行，作为法国－美国成功地进行的测高卫星项目Topex-Poséidon的继续。

21. 欧洲航天局小型飞行任务机会（SMO）组织目前正式考虑的飞行任务可按照下列参数进行分类：150至500公斤发射质量；600至900公里轨道；研制时间两年；平台和一体化的费用不超过4000万欧洲货币单位；轨道发送、采取委托方式及用户地面站小型飞行任务机会活动的基本概念是共同采购下述飞行组成部分的一部分或全部：发射设施、平台组合和地面部分。采用这种方式将能降低飞行任务中上述重复使用部件的成本。

22. 除了本报告其他部分所述向正在兴起的致力于空间技术的国家提供支助（技术援助及发射安排）外，美国航天局还采用了自己的小型航天器技术举措（SSTI）。该技术方案将减少科研和商业应用空间飞行的成本和研制时间。将实现有效载荷/总质量部分达到70 %，从研制到准备飞行的时间为两年。为了实现上述目标，应当通过利用商业和以性能为基础的规格表明小型航天器的新的设计和描述方法，将小型仪器技术纳入卫星总线设计和从终端到终端的产品研制及飞行核查。今后的美国航天局飞行任务能力将能够使费用降低30 %至50 %，将新技术用于飞行任务。

23. 美国航天局还在根据其“发现”号方案准备一系列小型、低成本行星科研飞行任务。这些飞行任务的目的是为了向研究行星界提供频繁的研究机会（每隔12至18个月进行一次发射），同时鼓励与业界建立合伙人关系。所有太阳系目标和物体都是“发现”号方案的有效的候选目标，但是航天器的成本应当低一些，运载火箭应当只限于Delta级或更小一些的。在第一次公布机会之后，一共收到了28项提案，涉及行星科研物体的各个方面（下次机会通报将于1996年5月公布）。前四项飞行任务已经得到了充分的资金，目前正在按计划进行，没有超过规定费用。

二. 其他科学和技术介绍

A. 空间碎片

24. 美国空间指挥空间监测系统对在近地球空间运动的物体进行定期跟踪和记录。该系统为监测近地球空间共使用了20多个雷达设施和几个光学设施，并保持有一份所有被跟踪物体的轨道成份目录（现在有8,000多个）。

可观测物体的最小直径分别为：低地球轨道 10 厘米，地球静止卫星轨道 1 米。主要使用专用光学系统——地球同步和深空间监测——来对地球静止轨道中的物体进行跟踪。另外，设在 Haystack（靠近马塞诸塞州的波士顿）的特殊雷达能够监测低地球轨道中直径不足一厘米的物体，并得出关于数量、通量、大小和高度的统计数据。在低地球轨道中似乎有 100,000 多个尺寸可到 1 厘米的空间碎片。

25. 西欧最大的雷达跟踪设施设在 Wachtberg-Werthhoven（德国）的应用科学研究所，该设施目前使用的是 34 米抛物面反射器天线。在对高危空间碎片进行重返预测时，从这里得出的数据是对目录数据的重要补充。欧空局已经主持了监测和跟踪中型碎片（1 － 50 厘米）的可行性研究。在使用光学望远镜进行碎片测量方面，欧空局将使用一台目前为了其他目的设在特那里夫岛泰德天文台（加那利群岛，北纬 28.3 度）的 1 米行星仪望远镜。在低地球轨道中可监测物体的最小的尺寸为 2 至 6 厘米，在地球静止轨道中则为 20 － 40 厘米。1997 年初，这台望远镜将被用于进行空间物体观测。

26. 有关小于 1 毫米粒子的信息主要是通过航天器机载特殊监测器或通过对暴露于空间环境的材料进行碰撞分析得出。欧洲的许多研究人员曾对在 1990 年 1 月回收后的美国航天局长期照射设施、欧洲可回收装载系统航天器和从哈勃空间望远镜上回收的太阳天线阵上的碰撞特征进行了分析。最大的洞的直径约 5 毫米。将使用这些分析的结果来验证目前使用的小型流体和空间碎片参照通量模型。

27. 对美国航天飞机轨道器的重返通过区、辐射器太阳板和其他表面进行的检查表明，环境模型低估了微型碎片的数量，并且随着时间的推移，碎片流正在增加。美国航天局的空间碎片破坏模型“防震器”预测，在 12 次航天飞机飞行中，需进行 13 次重返通过区的更换，而实际更换数为 19 次。在法国，从和平号空间站上（ARAGATZ 飞行）进行的为期一年的暴露于空间环境的试验中得出了另外一些数据，这些数据被用来与空间碎片环境模型进行对比。

28. 联合王国已经对拟议中的卫星星区可能遇到的独特的碎片危害进行了研究。卫星星区指的是卫星的分布式结构，它能提供全球定位、地球观测、手持个人通信、传呼或数据传送。有一些关于大量的新系统的建议，这意味着在 4 至 6 年的时间里将把 1,000 多个新卫星置于在 700 － 800 公里和 1,200 － 1,400 公里高度上的高倾角轨道中。这些项目一旦完成，将会使环绕地球

的空间中的某些区域汇集大量的卫星。

B. 在外层空间中使用核动力源的问题

29. 俄罗斯联邦已经对核动力源与空间碎片的可能冲撞进行了数字分析。特别研究了下列内容：对核动力源结构的破坏；在碰撞后核动力源轨道参数的变化；核动力源进行入大气层；可能出现的大气层破坏；以及辐射毒性材料粒子和核动力源的一部分结构的沉降物。曾考虑分析 1970 – 1988 年期间发射并被射入 700 – 1,000 公里高度轨道的反应堆与空间碎片的碰撞情况。与空间碎片的碰撞能够造成重大的核动力源损失，这种可能性极大，在 55 年之后有可能发生一次碰撞。

30. 对于核动力源和燃料棒在经过在最初重返流轨（高度： 160 公里）过程中出现的碰撞之后下降至大气层时发生的空气动力破坏情况进行的研究证实，核动力源结构已被破坏，并且反应堆的燃料插头（铀、钼合金）已被融化成不足一毫米的粒子。这些结果表明，这种核燃料粒子的沉降物能够使铀裂变产品在碰撞时衰竭，但不会导致沉降区的辐射水平的重大的变化。铍反应堆零件的下落和锂氢化物辐射屏蔽的部分失灵从致毒的角度来说也许会构成威胁，因此必须采取搜寻和清理（清除）措施。

31. 在联合王国，仍在继续研究是否有可能补充大会于 1992 年 12 月 14 日在其第 47/68 号决议中通过的《关于在外层空间使用核动力源的原则》。尽管在这一决议中包括了一些涉及协商，对受事故影响的国家提供援助，赔偿责任和赔偿等问题的重要的协商一致协议，但是仍然存在着一些局限性。其中包括：排除了推进和外星基地以及使用某些具体的技术来建立这些基地；忽视了空间碎片的潜在影响；并与为在地球上应用核能而制定的更为成熟的安全原则不符。因此，人们建议对其进行修改，以便以一种与在国际辐射防护委员会和国际原子能机构主持下随后出现的国际势态发展并行不悖的方式概括载于大会第 47/68 号决议中的意图。

C. 遥感

32. 继第一代印度遥感卫星的成功设计、开发、发射和在轨运转之后，印度朝向依靠第二代遥感卫星——IRS – 1C 和 IRS – 1D 来提供经改进和提高

的数据服务迈进了一步。IRS－1C于1995年12月6日发射，其特点包括：空间分辨率提高，频谱波段的范围扩大，并具有立体观测和快速重返的能力。IRS－1C飞行除了进行制图应用之外，主要涉及下列领域：在作物和植物方面开展应用，特别是进行混合作物和植物识别；在生物参数和海洋地貌中的应用，特别是观测风、海洋表面温度、浪等有形海洋地貌参数；在大气层中的应用，用以监测南极地区臭氧层耗竭等全球变化。

33. 摩洛哥在遥感和环境监测方面开展了一些空间研究活动，其特点是制定了积极、现实和长期的政策，既包括国家政策（协调、信息、培训和项目制订），又包括国际政策（参加各种论坛、国际委员会和双边和多边项目）。摩洛哥对外层空间的应用正日益发展、广泛和多样化。在卫星数据方面，现已将各台站投入运营，以便在国家气象局等地接收由气象卫星提供的天气卫星数据。计划成立两个国家海洋和大气层管理站，一个在国家气象局进行气象研究，另一个在摩洛哥皇家空间遥感中心接收高级甚高分辨率辐射计数据。这一台站将在GLOVE项目的框架内建立，该项目是由欧共体共同资助的。

34. 一家设在奥地利的名为GEOSPACE的公司正在为制作世界数字式地图实施一个全球测绘项目。全球卫星图象测绘项目的目标是发展出一种便于使用、符合成本效益并且便于经常获得最新数据的全球地球信息系统。现正在地方、区域和国际一级开展研究。

35. 国际摄影测量和遥感学会（摄影测量和遥感学会）秘书长审查了新的商业遥感卫星的状况。这些新卫星是为了提供气象学、制图学、自然资源和商业成象等领域分辨率最高可达2－5米的高分辨率数据。近年来从事这类商业遥感卫星开发工作的国家有法国、德国、印度、日本、俄罗斯联邦和美国。另外，欧空局在研制新的遥感卫星方面正在发挥主要作用。今后十年的前景是计划完成99个地球观测卫星有效载荷的建造工程，其中57个有效载荷应在今后五年内完成。新的有效载荷将对实现数字摄影测量和遥感发挥重要作用。

D．国际空间大学

36. 国际空间大学成立于1988年，其重点是跨学科、跨国家和跨文化的空间教育方案。国际空间大学为培养国际空间领域所需的专业人员，如创作人

员、创新人员、管理人员和指挥人员，作出了贡献。国际空间大学致力于培养教育与空间有关的各领域所有学科的专业人员，通过研究开拓和扩大知识范围，以及交流和传播知识及观念。

37. 国际空间大学的暑期班开设与空间有关的所有学科及其相互关系的综合性讲座。另外，夏季课程中还设计了一个国际空间项目，结果编写了一份对国际空间领域具有实际效用的专业报告。除暑期班方案外，国际空间大学最近还在法国斯特拉斯堡开设了空间研究硕士方案。这个为期一年的研究生方案包括三个主要内容：(a)科学和应用；(b)工程、系统和技术；(c)管理和社会科学。

E．空间运输

38. 俄罗斯联邦继续使用联盟号、闪电号和质子号等中型和重型发射装置将通信、科学和许多其他有效载荷射入不同的轨道（包括地球静止轨道）。旋风号和天顶号发射装置是与乌克兰合作生产的。世界上使用最频繁的航天器发射场——普列谢茨克发射场——负责俄罗斯 60%的发射任务，占全世界发射量的 10%。在其建成后的 30 年（自 1966 年 3 月起）当中，共发射成功了近 1,500 次。目前正计划在国家东部的斯沃博德内（阿穆尔地区）逐渐修建俄罗斯新的航天器发射场。

39. 改装的军用火箭 Start-1 号和威力更强大的 Start 号和 Rokot 号使用固体燃料，也将在空间方案中投入使用。俄罗斯的一家航天公司、乌克兰的一个研究与生产中心 Yuzhnoe 、一家美国公司和一家挪威造船公司目前正在一个国际联合集团的范围内开展合作，筹备从赤道附近的一个海上发射台进行商业发射。

40. 空间探索者协会支持和赞同“X大奖”的构想，这个大奖的金额为 1,000 万美元，将促进私营工业研制一种能运载 3 个成人（ 300 公斤）到地球上空至少 100 公里高度的可重新使用的单级亚轨道飞行器。空间探索者协会认为， X 大奖将激发人们对空间探索和开发的兴趣，并可促成将许多人送入空间的能力，这些正是空间探索者协会努力促进的目标。

F．天文学和行星探索

41. 1995 年初，代表联合国教育、科学和文化组织而公布的一项建议使国

际天文学界感到惊愕，这项建议是发射一个太阳反射器——“容忍之星”来庆祝其五十周年。这次活动的形式是一个双星，由两个反射气球组成（一个直径为 50 米，另一个为 30 米，两个气球由一条 2 公里长的绳索连接）。这个双星将在 1,250 公里的轨道上绕地球运行，其亮度与天狼星或甚至木星相等。值得庆幸的是这个项目被放弃了。这颗“双星”本身对天文学并不是一个灾难，但却是一个严重的障碍。令天文学界感到严重关切的是如果得以实施，将构成先例。这将是一个明确的信号，表明利用空间飞行的太阳反射器在国际范围传播信息是在文化、科学和教育上可以令人接受的。

42. 在射电天文学领域，绕轨道运行的卫星所发出的人为无线电波造成了一些问题。全球轨道导航卫星系统在 1612 兆赫频率上造成的干扰最近已得到解决。因此，重要的氧氢脉泽线在该频率上的观测条件将迅速改善。但是，一个新拟议的卫星通信系统——Iridium 系统，再次对射电天文学利用该波段造成威胁。虽然 Iridium 系统与美国国家射电天文观测台达成了一项谅解备忘录，但射电天文学界的其他方面有充分的理由将这个双边协议视作对今后一个不妥当的依据。所需要的是某种运营授权，使天文学、文明、工业和商业能够同时并存。

43. 另一个流动通信项目——Teledesic，正在 19 - 29 千兆赫波段的甚高频范围寻找能否分配得到一个频率，这是迄今为止尚未分配的一个毫米波长频段。这个频段区域是对射电天文学特别重要的一个频段区域，因为其中有许多星际射线发射。发现具有宇宙化学性质的这些特征将具有重要意义，有助于查明巨大的化学分子是如何形成的，以及这些过程在宇宙的什么地方发生。在分配用于通信目的的毫米频率波段时需要特别小心谨慎，这样才能保持获得这些意义重大的天文学资料的途径。

44. 1995 年 4 月 24 日至 26 日在纽约举行了国际近地物体会议。共同承办这次会议的有探索者俱乐部、行星学会和联合国。会议的主题——近地物体，是以可能与地球绕太阳的轨道相交的彗星和小行星为基础的。由于一般认为一个直径一公里的近地物体的冲撞可能对地球生物圈造成严重的后果，所以对其概率进行估算是有一定重要意义的。天文学和行星学已表明，环形陷坑是太阳系内层范围内行星、卫星和小行星的普遍特点，甚至是主要特点。对形成环形陷坑过程的记录进行的详细研究表明，直径一公里以上的近地物体的冲撞是一种经常发生的现象，在相当长的时标中连续不断。

45. 目前对近地物体研究的主要重点应是获得更多的知识，了解可在地球附

近空间环境中发生相互作用的小行星和彗星的起源、演变和动态及物质特征。人们对近地物体及可能发生冲撞造成的危害的认识有了进一步提高，但同时也必须相应地作出以科学知识为根据的负责任的解释。从这个角度来看，近地物体的研究提供了通过国际合作进行基本空间科学跨学科的科研机会。

注

1 《联合国大会第五十届会议正式记录，补编第 20 号》（ A/50/20 ），第 102 段。

*Annex**

SCIENTIFIC AND TECHNICAL PRESENTATIONS TO THE SCIENTIFIC AND TECHNICAL SUBCOMMITTEE AT ITS THIRTY-THIRD SESSION

CONTENTS

*This annex has not been formally edited.

I. SYMPOSIUM ON UTILIZATION OF MICRO- AND SMALL SATELLITES FOR THE EXPANSION OF LOW-COST SPACE ACTIVITIES

A. Use of Small Satellite Technology in Developing Countries

In view of the growing interest in the subject of small satellites, the International Academy of Astronautic (IAA) established in 1993, the Subcommittee on Small Satellites for Developing Nations. The Subcommittee considers small satellites to be a driving force for developing countries to initiate a space programme, train their personnel and develop their research and technological infrastructures. In most developing nations, at least two categories of needs for small and micro-satellite systems can be identified. The first group may be classified as direct needs, and relates to social and economical problems which may be addressed through various applications of space technology. The second group may be classified as indirect needs and deals with attaining the condition of taking full advantage of a country's investments in acquisition of space systems and services.

Direct needs can be further classified by geographic location, types of services and products or types of applications. Although some developing nations present some developed areas where the needs are very similar to those of developed nations, today it is more significant to focus on problems such as communications and monitoring of remote areas, agricultural land use and environmental protection.

The use of Low Earth Orbit Communications (LEOCOM) systems allows many services. One of the most interesting is the communication between a portable terminal and a normal telephone connected to the existing fixed telecommunication network. In this case, the two users may be located anywhere in the territory and, in particular, in remote areas or regions lacking a communications infrastructure. Communication between two mobile users as well as between a mobile user and a user of the fixed network system anywhere around the globe is also possible.

The use of automatic Data Collection Platforms (DCP), in conjunction with the two-way characteristics of LEOCOM allows for the installation of a data collection network which features wide coverage and provides real-time service. In addition, the LEOCOM system can provide the location of any user of mobile terminals with an accuracy in the hundred meter range. The LEOCOM mobile terminal can also be coupled to a facsimile machine for the transmission of graphical data. In this regard, for instance, it allows a user to send a facsimile of an electrocardiogram in the case of a medical emergency in a remote area.

Telemedicine is an application which will increase efficiency of medical services by allowing the transmission of information obtained by inexpensive and simple sensors directly to complex processing units in large medical centres where it might be interpreted by specialized physicians. This makes it possible for powerful and effective emergency services to reach poor and undeveloped areas, saving many lives and avoiding unnecessary displacement of patients. The Healthsat project is a very good example of a telemedicine application using a 60 kg micro-satellite in low Earth orbit (LEO) to relay medical data information between Nigeria and North America. Mobile communications may also play an important role in the case of natural disasters, allowing for help to reach the disaster victims earlier and providing logistic support to rescue teams.

Many developing nations have had an early access to the benefits of satellite remote sensing, but still have a long way to go in order to maximize the benefits allowed by the existing capabilities. There are, however, unique needs at both national and regional levels that demand new solutions. Brazil and the Republic of Korea for instance, are already developing new satellite programmes to address their specific needs. Developing countries in Latin America, South-East Asia and in other regions require special sensor parameters such as spectral bands, spatial resolution and time resolution. This in turn merits an examination of the cost of images, the level of investment in ground equipment, and the expertise required for utilization.

As a consequence of the relative lack of space science studies in the southern hemisphere, several natural phenomena that occur in the upper atmosphere in the tropical and southern hemisphere zones are not adequately understood. This concerns, for example, the ionospheric plasma depletions which occur over South America and strongly interfere with radio communications as well as the South Atlantic Anomaly which is well known for the occurrence of energetic particles stemming from the inner radiation belt and causing severe damage to, or even complete destruction of, satellite instrumentation. Therefore, it seems highly advisable that developing countries that are located in the southern hemisphere and, in particular, in the tropical zone, join the global effort towards improving the knowledge of their own space environment. Many such countries have been engaged in astrophysical studies (particularly of the sky regions which are not observable from the northern hemisphere) in the past few decades and small satellites would be an important means of complementing these ground-based studies.

Cooperative space activities are often supported by some kind of technology transfer. A successful technology transfer in the development of a small satellite project implies a process by which a team acquires sufficient momentum to be able to produce the next generation of small satellites. There are several mechanisms whereby technology transfer can be achieved, but to be successful, the transfer should be a transfer of understanding, not the transfer of a technology package (know-why as well as know-how). Examples of programmes where engineers from developing countries are trained on small satellite design, production and operations are numerous. The University of Surrey of the United Kingdom has, for example provided such assistance in the development of small satellites weighing less than 100 kg to Chile, Pakistan and the Republic of Korea, as well as to small countries in Europe that have decided to initiate a space programme.

There are several ways to obtain launch access for small satellites, either on a purely commercial basis or through participation in international cooperative agreements. A country may also consider developing its own launch capability. A driving force in pursuing this approach is the lack of available low cost launchers and an inability for the country to meet their launch requirements on a timely basis if the country views access to space as critical to their national development. Acquisition of launch services from international commercial sources is sometimes preferable to cooperative arrangements, due to difficulties in finding an appropriate exchange opportunity. In particular, countries seeking their first launch may find a commercial acquisition the most effective route open to them.

Cooperative missions may be considered when a clear programmatic benefit is shared by more than one country with a mutual desire to maximize their unique national resources and available funding. International cooperative agreements vary from mission to mission and country to country. Most require a particular country to assume full financial and technical responsibility for its portion of the cooperative effort. In general, in the event of such a division of labor, clean and distinct managerial and technical interfaces should be detailed in such agreements.

B. Example of Cooperative Microsatellite Projects

Microsatellites UoSAT 3 and 5, KITSAT 1 and 2 and PoSAT 1 provide examples of the use of a microsatellite platform for collaborative space science research between the University of Surrey (United Kingdom), the Korea Advanced Institute of Science and Technology (KAIST) and Portuguese research institutions. A small payload monitors the near-Earth radiation environment and provides an important opportunity to validate ground-based numerical models with flight data yielding simultaneous measurements of the radiation environment and its effects upon on-board systems.

The University of Surrey has pioneered microsatellite technologies since beginning its UoSAT programme in 1979. The need to accommodate a variety of payload customers within a standard Ariane Structure for Auxiliary Payloads (ASAP) launcher envelope, coupled with increased demands on packing density, economy of manufacture and ease of integration, catalyzed the development of a novel modular design of a multi-mission platform. It is based around a series of standard module trays which house the electronic circuits and themselves form the mechanical structure onto which solar arrays are mounted. Electronically, the microsatellite uses modern, sophisticated (but not necessarily space-proven), electronic circuits to provide a high degree of capability. These are underpinned by space-proven subsystems resulting in a layered architecture that achieves redundancy by using alternative technologies rather than by simple duplication.

Communications and Earth observation payloads require an Earth-pointing platform. Therefore, the microsatellite is maintained to within two degrees of the center of the Earth line by employing a combination of gravity-gradient stabilization (using a six meter boom) and closed-loop active damping using electromagnets operated by the on-board computer. Attitude determination is provided by Sun, Earth horizon, star field, and geomagnetic field sensors, while orbital position is determined by an on-board Global Positioning System (GPS) receiver. Electrical power is generated by four body-mounted Germanium Arsenic (GaAs) solar array panels (each generating around 35W) and is stored in a 7Ah NiCd rechargeable battery. Communications are supported by VHF up links and UHF down links, capable of transferring several hundred kBytes of data to brief-case sized communications terminals.

Various constellations of small satellites in LEO have been proposed to provide world-wide communications using only hand-held portable terminals which broadly fall into two main categories: real-time voice and data services and non-real-time data transfer. The close proximity of the satellites in LEO to the user and the consequent reduction in transmission loss and delay time appear attractive when compared to traditional communications satellites in a distant geostationary orbit. This holds out the promise of less expensive ground terminals and regional frequency reuse. The communications characteristics associated with a LEO constellation pose however, quite different and demanding problems, such as varying communications path and links, high frequency shifts, and hand-over from satellite to satellite.

Microsatellites can offer quick turn-around and inexpensive means of exploring well-focused, small-scale scientific objectives (*e.g.* monitoring the spacer radiation environment, updating the international geomagnetic reference field. etc.) or providing early proof-of-concept prior to the development of large-scale instrumentation in a manner, fully complementary to expensive, long-gestation, large-scale space science missions. The UoSAT missions have demonstrated that it is possible to progress from concept through to launch and orbital operation within 12 months and a budget of $4 million. This not only yields early scientific data, but also provides opportunities for young scientists and engineers to gain "real-life" experience of satellite and payload engineering and to be able to initiate a programme of research, propose and build an instrument, and retrieve space data for analysis and presentation for a thesis within a normal period of postgraduate study.

Conventional Earth observation and remote sensing satellite missions are extremely costly - typically over $200 million each. The development of high-density two-dimensional semi-conductor charged coupled device (CCD) optical detectors, coupled with low-power consumption microprocessors, presents a new opportunity for remote sensing using inexpensive satellites. Clearly, the limited mass, volume, stability and optics of microsatellites cannot compete with traditional large-scale missions such as Landsat, SPOT and ERS. However, for medium resolution and meteorological-scale imaging, the KITSAT and PoSAT satellites have demonstrated a comparable facility but at a tiny fraction of the cost. This is attractive for developing nations in particular that are interested in possessing an independent remote sensing facility under their direct control at a very modest cost, even if the resolution is limited.

The latest PoSAT 1 microsatellite carries two independent cameras providing a wide-field ground resolutions of 2 kilometers for meteorological imaging and a narrow-field ground resolution of 200 meters for environmental monitoring with 650 nanometers optical filters providing good separation of arid/vegetation and land/sea boundaries. The future mini-satellites of this series will support Earth imaging cameras yielding better than 100 meter resolution with three spectral bands.

Microsatellites also provide an attractive and low-cost means of demonstrating, verifying and evaluating new technologies or services in a realistic orbital environment and within acceptable risks prior to commitment to a full-scale, expensive mission. Examples of this opportunity include new solar cell technologies, modern Very Large Scale Integration (VLSI) devices in space radiation as well as demonstrations of advanced communications. Because satellites depend upon the performance of solar cell arrays for the production of primary power to support on-board housekeeping systems and payloads, knowledge of the long-term behavior of different types of cells in the radiation environment is essential. Unfortunately, ground-based, short-term radiation susceptibility testing does not necessarily yield accurate data and hence there is a real need for evaluation in an extended realistic orbital environment. This can be accomplished easily and cheaply on-board microsatellites.

Although microsatellites are physically very small, they are nevertheless complex and exhibit virtually all the characteristics of a large satellite. This makes them particularly suitable as a focus for the education and training of scientists and engineers by providing a means for direct, hands-on experience in all stages and aspects (both technical and managerial) of a real satellite mission - from design, construction, testing and launch to orbital operation. The very low cost, rapid time frame and manageable proportions makes this approach very attractive to countries wishing to develop and establish a national expertise in space technology. In this connection, according to the experience of the University of Surrey, collaborative education programmes typically have the following elements: academic education (MSc., PhD degrees), on-the-job training on a real microsatellite mission, cooperation on establishing and operating ground stations with participating countries, and finally the necessary technology transfer (design license).

C. Small Satellite Projects in Latin America

A small satellite project in Argentina, Scientific Application Satellite B (SAC-B), is being prepared in cooperation with the United States. The main purpose of the project is to design a satellite with a scientific payload to advance the study of solar physics and astrophysics. The mass of the satellite is about 180 kg with an expected active lifetime of a minimum of three years. It will have a circular orbit at 550 kilometers that has an inclination of 38 degrees. On-board experiments include an examination of energetic particles and radiation from solar flares, the localization of sources of intense transient emissions of gamma ray radiation, the monitoring of galactic and extragalactic X-Ray diffuse background and examination of energetic neutral atoms in radiation belts (in cooperation with Italy). The launching of this satellite is scheduled for 1996. A new generation of satellites designed for scientific research and remote sensing, SAC-C and SAC-D, is being prepared for launch in 1999 through 2006.

In Brazil, great significance is attached to the collection of data from remote platforms using space technology. The Brazilian Complete Space Mission (MECB) successfully started in February 1993 by the launch of the Satelite de Coleta de Dados (SCD 1) satellite. It is a small 105 kg spinning satellite for collection and distribution of environmental data acquired by data collecting platforms distributed over Brazilian territory, mainly in the Amazona region. The satellite has remained operational for two years after its expected useful life (1 year). At least two similar satellites will be launched to ensure continuity of the mission. In addition, the improved SCD 3 satellite (200 kg) would have the mission of proving the concept of voice and data communications in the equatorial region.

The Equatorial Communicator (ECO-8) study is funded mainly by the Brazilian government. A system of 8 satellites in equatorial orbit at 2,000 kilometers altitude can provide constant coverage of regions up to 30 degrees on both sides of the equator. It is intended for voice communications between mobile terminals or between a mobile and a fixed terminal. It can also provide a real-time, uninterrupted dissemination of data collected by automatic platforms located anywhere in this equatorial belt. ECO-8 would require no communication links between satellites and allow for at least 200 simultaneous connections. The Equatorial Constellation Communication Organization (ECCO) is planned for the implementation and operation of wide area personal communications (including cellular-quality voice, data and fax) to rural and remote areas in the equatorial region. The ECCO system, scheduled to begin full operation in the first quarter of 1998, will consist of 12 satellites (including one spare). It will reach over 100 countries in Latin America, South Asia, Africa and the Middle East. This would mean that more than 35 percent of the total land mass and more than 40 percent of the world's population would be covered by this system.

The first Brazilian microsatellite for scientific application, SACI-1, should be launched in October 1997 as a piggyback to the China-Brazil Earth Resources satellite (CBERS). The payload of SACI-1 is composed of four scientific experiments - measurement of Earth air glow emissions, measurement of the anomalous cosmic radiation fluxes, investigation of plasma bubbles and investigation of the geomagnetic field effect on charged particles. The ground segment should consist of two receiving stations in Brazil and users ground data collecting stations. A cost effective LAN PC-based tracking and control system will be implemented and scientific data as well as payload on-board configuration will be distributed through the Internet in order to decentralize and facilitate the interfacing between the payload and its customers.

In Chile, the first operational satellite will be FASat-Bravo, developed in cooperation with the University of Surrey. This 46 kg microsatellite would be put into circular orbit at 650 kilometers with an inclination of 82.5 degrees in August 1996. It will carry ozone layer monitoring experiment, a data transfer experiment, an experimental Earth imaging system and other equipment, including an educational experiment. Using the communications link provided by the satellite, students will be able to engage in study activities (orbital mechanics, satellite communications analysis, telemetry analysis etc.) one or two days per month. In fact, a similar microsatellite, FASat-Alpha, was launched into orbit as a piggyback to the Sich-1 satellite on-board a Tsiklon booster on 31 August 1995. The object separated normally from the booster, but the microsatellite failed to separate from Sich. The problem with the pyrotechnic device is now being studied to assure its proper functioning next time.

D. Microsatellite Project of the Republic of Korea

The Satellite Research Center of the Korea Advanced Institute of Science and Technology (KAIST) began its programme to develop space technology with the launch of two scientific and experimental microsatellites KITSAT 1 and 2 in 1992/93. An agreement worth $4.6 million was signed in 1990 by KAIST with the University of Surrey, covering training, two microsatellites and a ground station. Students took the university MSc courses in Satellite Communications and Spacecraft Engineering. The second microsatellite was build in Korea, using the experience gained during the preparation of the first microsatellite in the United Kingdom. Through this first step into space, the KAIST has trained many engineers and scientists and successfully acquired microsatellite systems technologies.

Currently, KAIST is involved in designing its new indigenous satellite KITSAT 3 to enhance the capabilities of the previous two microsatellites. A primary objective of this programme is to develop a microsatellite system which has highly accurate attitude control and high speed data transmission. It shall also provide hands-on experience to Korean space industries and research institutes. KITSAT 3 will carry a remote sensing multispectral pushbroom CCD camera and several space science experiments. The remote sensing payload will be able to monitor environmental disasters such as floods, volcanic eruption and earthquake damage in the Asia-Pacific Region. The space science experiments should measure the distribution of highly energetic particles in Earth radiation belts and geomagnetic field intensity around the mission orbit and also monitor the total dose of radiation encountered by the solid state memory device.

The total mass of the KITSAT 3 microsatellite will be less than 100 kg and the dimensions of the main box-like body are approximately 45 cm by 45 cm by 60 cm. The satellite consists of a sensor platform, a payload platform, a reaction control unit, a bus platform and a battery with adaptor. The GaAs solar cells are expected to generate more than 100 watts when fully illuminated and not to be degraded by more than 30 percent after three years of mission life. There are three solar panels; two of which are deployable (unlike the first two microsatellites), while the third is fixed on the main body. The attitude control system uses reaction wheels and enhanced magnetorques to achieve full 3-axis stabilization.

The KITSAT 3 is expected to be launched into heliosynchronous polar orbit with an altitude of about 800 km in the middle of 1997. An engineering model will be completely manufactured and tested by the end of April 1996. It also includes a qualification test for the launcher which should also be selected this year. Future planned missions in Korea include the development of the advanced small satellite KITSAT 4, based on KITSAT 3 architecture. This small satellite of a 300 kg should include a new 5 meter resolution linear CCD camera system and a demonstration of a hybrid propulsion system.

E. Microsatellite Project of the Republic of South Africa

In South Africa, the SUNSAT microsatellite project was started in 1992 to increase engineering design opportunities for graduate students and to increase industrial and international interaction with the Stellenbosch University. The microsatellite has the mass of 60 kg and is basically box-shaped with dimensions 45 cm by 45 cm by 60 cm and should provide satellite images of cultivated fields, natural vegetation and pollution around the globe. It shall also include an electronic mailbox orbiting Earth to receive and deliver messages; speech and data relay experiments to schools; a unique method of training graduate students; and research in satellite engineering. SUNSAT should be launched by a United States Delta launcher in March 1997 into polar orbit at 450 to 850 kilometers (originally, heliosynchronous circular orbit had been envisioned), together with the Danish magnetospheric research satellite Oersted. SUNSAT will also carry the GPS navigational receiver of the National Aeronautic and Space Administration (NASA) of the United States, and a set of laser reflectors for precise positioning experiments.

The SUNSAT microsatellite was developed by about 28 graduate students who designed and built most of the electronics and about half of the mechanics, with the assistance of technical personnel of the

Engineering Faculty (technical drawings, printed circuit board layout and manufacturing of the body structure). Solar panels are located on all four sides of the satellite and can deliver 140 watts of power to rechargeable NiCd batteries. Attitude determination is made by horizon, Sun and star sensors as well as by a magnetometer. Orientation control is provided by reaction wheels, magnetorquers and a gravity gradient boom. A high resolution camera can image the Earth in three colours and stereo. Its spatial resolution is 20 meters from 800 kilometers altitude.

F. Small Satellite Projects in Spain

Spain was one of the first countries to develop its own satellite. On 15 November 1974, a United States Delta launcher put into orbit, the INTASAT satellite weighing about 25 kg with a 45 cm diameter, corresponding to what is now called a microsatellite system. This technological satellite measured space radiation and, using its solar batteries, functioned in a 1450 km orbit for a full two years. Unfortunately, there was no immediate continuation of this successful project and Spain got involved in larger scale projects (communications satellites of the HISPASAT series and participation in ESA projects). It was only on 7 July 1995 that a second Spanish microsatellite UPM-Sat 1 was launched by an Ariane 4 rocket into a 650 kilometer circular heliosynchronous orbit. It was developed at the Universidad Politécnica in Madrid and has a mass of 47 kg.

UPM-Sat continues experiments started twenty years ago by INTASAT and its development has strengthened cooperation between academic and industrial entities in the country. There are plans for the launching of satellite UPM-Sat 2 (nicknamed MATIAS, for Mediciones Atmosféricas, Telecomunicationes, Ingenieria y Aplicaciones de los Satélites) in 1998. The main purpose of this satellite is to investigate atmospheric pollution and provide for data collection and transmission. Another project, Vehicle for Education of the Network of Universities in Space (VENUS) is currently being negotiated with several interested universities in Europe and Latin America. It could be realized under the UPM-Sat 3 series of satellites.

Another Spanish space project, MINISAT, was entrusted to Instituto National de Técnica Aerospacial (INTA), by the Spanish Inter-ministerial Commission for Science and Technology (CICYT) in 1992. Modular satellites of 180 to 500 kg mass (depending on the number of modules used) would be launched by Pegasus airborne launchers starting in 1996. The first satellite MINISAT 01 will consist of the basic platform and will be used for scientific research (monitoring of the diffusion of extreme ultraviolet radiation in the atmosphere, detection of low-energetic gamma radiation and materials science). Satellite MINISAT 1 will be an upgraded version, equipped for remote sensing observations. MINISAT 2 will use the basic platform to provide long-distance communications even from the geostationary orbit. In addition, INTA has been recently involved in the programme NanoSat, aimed at the development of a 20 kg microsatellite for communication with the Spain's scientific base Juan Carlos I in Antarctica. The project was initiated in 1995 and targeted for satellite launch in 1998.

G. Small Satellite Projects in Central Europe

A small scientific sub-satellite MAGION 4 was launched on 3 August 1995 together with the INTERBALL 1 "mother" satellite. MAGION 4 separated from the mother satellite after reaching the planned orbit (apogee 191,907 kilometers, perigee 793 kilometers, inclination 63.0 degrees). The satellite has a mass of 60 kg and was developed by the Institute of Atmospheric Physics (Czech Republic), the Technical University Graz (Austria) and the Space Research Institute (Russian Federation). Its scientific payload is aimed at the study of geomagnetic field, wave phenomena and plasma parameters of the ionosphere in frame of the INTERBALL space project. Simultaneous measurements from two satellites, which move along practically the same orbit at a relatively small distance from each other, allow for temporal and spatial resolution of the observed phenomena.

During the initial period of about two months after launch, the spatial orientation of the orbit enabled study of the magnetopause and bow-shock regions, while from October 1995 to January 1996, the satellite orbit was in the region of geomagnetic tail. On 9 January 1996, the distance between the two spacecraft reached 43.5 minutes along the orbit (MAGION 4 crossed "the same" region of space 43.5 minutes earlier). The MAGION 4 on-board thruster (using pressurized gas designated also for reorientation of the spin axis to the Sun) changed the orbit several times in January-February 1996, so that both satellites should again be close together in May 1996. The ability to control the separation distance is important for the study of fine structures of the magnetopause, bow-shock and solar wind plasma. Similar twin satellites should be launched into the geomagnetic polar region as part of the INTERBALL project in July 1996.

The Central European Satellite for Advanced Research (CESAR) is a spacecraft of about 300 kg that will fly in orbit with a 400 kilometers perigee, 1000 kilometers apogee and 70 degree inclination. The scientific mission is related to the study of the magnetosphere, ionosphere and thermosphere (MIT) environment. Ten different experiments, provided by scientists from Austria, Czech Republic, Hungary, Poland and Slovakia will be accommodated on-board the spacecraft which is funded by the Italian Space Agency, ASI, and designed by Alenia Spazio. This mission is one of the objectives of the cooperation among the countries of the Central European Initiative (CEI).

A feasibility study for CESAR has been started and a detailed technical study funded by ASI will be conducted by Alenia Spazio concerning the spacecraft's system engineering. The participating countries will develop the experiments they are responsible for and will collaborate with each other regarding on-board accommodations for the experiments.

The nominal mission lifetime will be two years which will allow a sufficient period of observation of the complex MIT phenomena. The evolution of the initial orbit will be determined by natural perturbations since no propulsion capability is provided on-board. The once-per-orbit perigee-apogee excursion, combined with the slow procession of the orbital plane with respect to the Sun and the Earth, will provide the payload with complete sampling of the near-Earth environment between 400 and 1000 kilometers and ±70 degrees latitude in all conditions of illumination over the lifetime of the mission.

The spacecraft should be launched by direct injection into its required orbit by a small launcher (either an improved Scout or Pegasus). Deployment of the solar array and S-band antennas will follow separation. The spacecraft will be attitude stabilized by spinning around a sun-pointing axis with a rate of 4 rpm. The spin rate will provide the experiments with a fast scan and sampling of the environment surrounding the spacecraft. Boom mounted experiments will be deployed after attitude acquisition. About one month of spacecraft commissioning and experiment calibration will follow. After the nominal operation of the satellite has been certified, the science mission will be carried out for the following two years.

The present configuration foresees a mass budget of about 151 kg of service module and 95 kg of payload module for an operative launch configuration mass of 246 kg. A mass margin of 20 percent is accounted for in the next phase of the project to take into account increases that will surface during the development process. The spacecraft is expected to be completed before the end of 1997 for a launch at the beginning of 1998. CESAR will be the first spacecraft of a series that will also include a second spacecraft currently in preparation, the Joint Ultra Violet Night Sky Observer (JUNO), a UV astronomy satellite being developed in cooperation with NASA. A definition phase study for JUNO is underway.

H. French Small Satellite Projects

A working group on small satellites was created by the Centre National d'Études Spatiales, France (CNES) at the end of 1993 to propose recommendations for the development of a series of small satellites complementing the SPOT system, at a cost of less than 300 million French francs per mission and development time of two years. The recommended programme, Platforme Reconfigurable pour l'Observation, les Télécommunications et les Usages Scientifiques (PROTEUS) is a satellite that should have a mass less than 500 kg (including 250 kg of useful payload), available power of 100 to 300 watts and pointing accuracy of 0.1 to 3 degrees. Technological studies were performed during 1994/95, ending by the selection of industrial partners. The first flight is envisioned in 1999 as a continuation of the successful France - United States altimetric satellite project Topex-Poséidon. Possible orbits are at 500 to 1400 kilometers and satellite should be able to maneuver and change its orbit with a total velocity change of 60 to 180 m/s.

Possible scientific missions using the PROTEUS platform include astronomy (project SAMBA for registration of local fluctuations of 3K background radiation from the Big Bang and COROT for asteroseismology), space environment (IBIZA for registration of the plasma accelerated in the geomagnetic aurora regions), Earth sciences (TPFO, Vagsat, Irsute, Tropiques), and fundamental physics (QUICK-STEP for verification of the equivalence of inertial and gravitational mass). From applications missions, priority is given to radio communications and optical observations. In parallel with the PROTEUS platform, CNES is making studies of a microsatellite with less than 100 kg of mass. It would be used mainly as a test platform for new technological concepts.

I. Small Satellite Missions of ESA

The missions which are being considered by the Small Missions Opportunities (SMO) initiative of the European Space Agency (ESA) may be classified by the following parameters: 150 to 500 kg launch mass, orbit between 600 and 900 km, development time of about two years, cost of less than 40 million ECU for platform and integration, delivery on orbit, commissioning and user ground station. This is a class of small missions which is generating a lot of interest, and where the European industry is not yet as competitive as it is in the microsatellite field. In this regard, European industry, through its trade association Eurospace, came to ESA with the suggestion that ESA should pool together a sufficient number of missions, from ESA's own programs and from those planned by Member States. Various ESA Member States have flown, are developing or are planning small missions. With few exceptions, these missions have involved or will involve development of a single spacecraft. When more spacecraft are to be realized, this will happen at 3 to 4 year intervals.

The basic idea of the SMO initiative is to have a common procurement of part or all of the following mission elements: launch, platform integration and ground segment. This approach should achieve low cost benefits for recurrent elements of a mission, while preserving the user's control over the mission payload and operations. The possibility of efficiently integrating a number of different missions on a common subset of equipment has already been demonstrated by various small satellite programs, such as NASA's Small Explorers. Actual contents of the SMO initiative will be defined after an analysis of proposed mission requirements, which will be performed in the second phase of on-going studies. At present, the launch opportunity seems to be the strongest common denominator.

If the SMO initiative is successful, Europe will have an SMO Operator, able to deliver a scientific or commercial payload in orbit at low cost. Because this initiative addresses a user community with different levels of capability (some Member States have an autonomous SMO capability, some do not), the SMO Operator will be ideally suited to fulfill the different needs of emerging countries. Participation in the SMO initiative could take at least two forms: via another international organization, with a mission dedicated to emerging countries, or via agreement with a participating ESA Member State. Assuming a Member State decides this year to support the SMO initiative, a program could start as early as 1997 and the first launch would take place towards the end of 1999.

J. Small Satellite Technology in the United States of America

In addition to the support (technological assistance, launching arrangements) provided to emerging space-faring nations, as described in other parts of this report, NASA has adopted its own Small Spacecraft Technology Initiative (SSTI). This technology programme should reduce the cost and development time of space missions for science and commercial applications. It should achieve a payload/total mass fraction of up to 70 percent. Time from development to flight readiness should be two years. To achieve those goals, new design and qualification methods for small spacecraft should be demonstrated using commercial and performance-based specifications, integration of small instrumentation technology into the satellite bus design and end-to-end product development and flight verification. The future NASA mission capability should result in 30 to 60 percent reduction of costs and new technology insertion into missions.

The first two satellites, named Lewis and Clark, will carry more than 30 different technology demonstrations. Lewis will fly three instruments, including a "hyper-spectral imager" having 384 spectral bands (the operational LANDSAT satellite only has seven bands). It is designed to enhance traditional remote sensing applications in agriculture, global environmental monitoring, forestry, land management and industrial planning. Clark will carry four scientific payloads combining a very high 3 m resolution optical imager with stereo-imaging capabilities. This will be used for commercial remote sensing, disaster management and urban planning. The satellites will have a mass of 272 and 317 kg respectively, from which about 70 percent accounts for the scientific payloads (in existing satellites, it is typically 40 percent). The launch vehicle will most likely be the Pegasus-XL. The Integrated Product Development team, which will manage the project, consists of more than 35 members from the manufacturing company, NASA centers, universities and high schools.

One of the innovative, yet not well publicized projects, is the GPS Gravity field modeling. The first satellite to carry a precise GPS receiver was Topex/Poseidon oceanographic satellite. Its data had been combined in a new model of the Earth gravity field which illustrated the power of this method. To improve this model, the GPS atmospheric occultation project needs many transmitters and receivers aloft at once, densely sampling the global atmosphere every few hours. The preliminary proposal is for twelve satellites launched at once into a single orbit plane by 1998. Until the arrival of GPS and low cost microsats, the evident cost of such an enterprise made it impractical within Earth science programmes. Space borne GPS imaging will have a profound impact on ionospheric science. The ability to image ionospheric structures continuously in three dimensions will help scientists to examine in detail the evolution of "space weather", to trace the formation of geomagnetic storms, and perhaps one day to predict when an observed solar flare will cause disruption on Earth.

NASA is also preparing a series of small, low-cost planetary science missions under its Discovery programme. They are designed to provide frequent investigative opportunities (one launch every 12 to 18 months) to the planetary research community while encouraging partnerships with industry. All solar system targets and objectives are valid candidates for the Discovery programme, but the spacecraft cost should be low and the launch vehicle will be limited to Delta class or smaller. A total of 28 proposals had been received in response to the first announcement of opportunity, covering the full range of planetary science objectives (next announcement of opportunity is to be released in May 1996). The first four missions are now fully funded, and their development is on schedule and within cost guidelines.

The first of the Discovery missions, called NEAR (Near Earth Asteroid Rendezvous) was launched on 17 February 1996 towards an encounter with asteroid 433 Eros. The initial close pass at Eros will occur on 6 February 1999 at a distance of about 500 kilometers. The spacecraft should be then maneuvered even closer to the asteroid (below 25 kilometers) and orbit it for about one year, making precious measurements of its characteristics. Mars Pathfinder is the second Discovery mission planned for launch on 2 December 1996, and should land on Mars on 4 July 1997. It should investigate the structure of the Martian atmosphere, monitor surface meteorology, observe surface geology and measure elemental composition of the rocks and soil. The third small planetary mission, Lunar Prospector, will be launched in June 1997. Its science objectives include a global mapping of surface chemistry, search for the presence of ice near lunar poles, detailed investigation of magnetic and gravity fields at high resolution and identification of possible gas release events. A comet-sample return mission (launch in February 1999) will be the fourth Discovery flight during which Stardust will rendezvous with comet Wild-2 in January 2004. It should return to Earth the first samples of comet material in January 2006.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

A. Measurements of Space Debris

The largest radar tracking facility in western Europe is at FGAN (Research Establishment for Applied Science) at Wachtberg-Werthhoven (Germany). FGAN operates an L-band tracking and Ku-band imaging radar using a 34 meter parabolic dish antenna. Data from this site are an important addition to the catalogue of data in the case of re-entry predictions for high-risk space debris. ESA has sponsored research of the feasibility of detecting and tracking medium-size debris (1 to 50 centimeters) with L-band radar. Metal spheres of 5 centimeter diameter are measured frequently and one meter objects are detectable in the geostationary orbit (GSO) using a multi-pulse signal processing techniques. A one day beam park (fixed antenna position) experiment has been carried out jointly with the Fylingdales station (United Kingdom). Hardware and software upgrades are being implemented to enhance the detection performance of the existing Tracking and Imaging Radar (TIRA) for medium-size debris in Low Earth Orbit (LEO). A further beam park experiment is planned in the bi-static mode with the radiotelescope at Effelsberg. The measurements will be used to validate and improve current environmental models.

Regarding the debris measurement by optical telescopes, ESA will use a one-meter Zeiss telescope which is currently being installed at the Teide Observatory on Tenerife (Canary Islands, 28.3 degrees north latitude) for other purposes. The configuration of this Ritchey-Chrétien-Coudé system has been extensively analyzed with respect to possible changes and upgrades to enable space debris observation and tracking. The optical system dedicated to space debris measurement will cover the spectral range from visible to near infrared and will have a field of view of 0.6 degrees. As a detector, a nitrogen cooled CCD camera with a mosaic of four 2048x2048 chips is under consideration. Special methods and computer algorithms are required to extract from CCD data the orbital parameters and other characteristics of space objects. The minimum size of detectable objects will be 2 to 6 centimeters in LEO and 20 to 40 centimeters in GSO. The telescope should be operational for space object observations at the beginning of 1997.

Objects moving in near-Earth space are regularly tracked and catalogued by the United States Space Command (USSC) Space Surveillance System. This system operates more than two dozen radar and several optical facilities to monitor near-Earth space. It also maintains a catalogue of orbital elements of all tracked objects. The minimum diameter of observable objects is about 10 centimeter for LEO and 1 meter for GSO. Objects in GSO are tracked mainly by the dedicated optical system GEODSS (Geosynchronous and Deep Space Surveillance). Currently, orbits are maintained for over 8,000 objects and the USSC Catalogue is the main source of essential information for detecting breakups and monitoring growth of the debris environment. Current surveillance systems have difficulties in cataloguing some space objects in highly elliptical orbits (HEO) and low-inclination orbits. Objects in HEO are more difficult to detect because they spend a large fraction of their time at very high altitudes, and objects in low-inclination orbits because of the relative lack of sensors at low latitudes.

In addition, a special radar located at Haystack (near Boston, Massachusetts) is capable of detecting objects less than 1 centimeter in diameter in LEO and obtain statistical information on number, flux, size and altitude (but not complete orbital information). There seems to be over 100,000 pieces of space debris in LEO at sizes down to 1 centimeter. The Haystack data suggest that there may be major sources of centimeter-sized orbital debris other than previously recorded breakups. The large number of objects in orbits between 900 and 1,000 kilometers with orbital inclinations between 60 and 70 degrees have relatively smooth and spherical shapes (according to the polarization data), rather than the irregular shapes that would typically be created in a breakup. This combination of orbital and physical characteristics suggests that these objects may be tens of thousands of 0.6 to 2.0 centimeter liquid droplets of a sodium/potassium coolant leaking from the nonfunctional cores of Russian nuclear power sources (NPS) satellites. Also NASA's deep space tracking radar at Goldstone (California) confirms the existence of this type of debris. This radar, capable of detecting 2 millimeter objects at 600 kilometers is only available for space debris measurements for a few hours per year.

A dedicated optical Schmidt telescope with a main mirror of 32 centimeter aperture, located at Haleakala site (Maui, Hawaii) is able to detect 60 centimeter objects in the GSO. During 252 total hours of observation from 1992 to 1994, it revealed that about 30 percent of objects detected by its CCD sensor appeared to be debris. In the future, much larger liquid surface mirror telescope will be used for observation of GSO objects. Recent new technology enables construction of the 3 meter diameter rotating mercury mirror, equipped with a hypersensitive CCD detector and with full computer control.

Information on particles smaller than about 1 millimeter is obtained mostly through special detectors carried by spacecraft or through the analysis of impacts on material that has been exposed to the space environment. For the first time, an impact detector will be placed on a geostationary spacecraft. A spare dust detector of Galileo/Ulysses probes, developed by the Max-Planck Institute for Nuclear Physics at Heidelberg (Germany), will be flown this year on the Russian EXPRESS 2 spacecraft. In the framework of the EUROMIR 95 project, dust and debris impact experiments are carried out outside the MIR space station. On the external platform European Science Exposure Facility (ESEF), a number of experimental cassettes have been installed. The cassettes have been retrieved during the extra-vehicular activity of the cosmonauts on 8 February 1996 and returned to Earth on 29 February 1996.

Many European researchers have analyzed impact features on NASA's Long Duration Exposure Facility (LDEF) after its retrieval in January 1990, following 69 months in orbit at altitudes between 340 and 470 kilometers. Of the more than 30,000 LDEF craters visible by naked eye, 5,000 have diameters larger than 0.5 millimeter. The largest crater (5 millimeters) was probably caused by a 1 millimeter particle. In general, it is difficult to determine the composition of an impacting particle and therefore to distinguish between impacts of micrometeoroids and artificial space debris. The European Retrievable Carrier (EURECA) spacecraft, launched in July 1992 was retrieved by the space shuttle after 326 days in orbit at a mean altitude near 500 kilometers. The spacecraft has since then undergone extensive postflight analysis with regard to impact features. It revealed 71 impact sites on the thermal blankets, and 14 impacts on the body plates, including the largest impact feature with 2 millimeter crater diameter. Also EURECA's solar arrays of 96 square meters total surface area were scanned by different European research groups. More than 1,000 impacts were detected on the front side of each of the two wings, while only about 44 were noticeable on the rear sides. From a total of 847 of the larger impact sites, high resolution microphotographs were taken. The largest impact crater diameter is 6.4 millimeters, resulting from an object of 0.5 to 1 millimeter diameter. Further analysis will concentrate on impactor characterization (e.g. mass, direction, velocity, chemical composition) and on hypervelocity calibration experiments conducted with the spare solar array surface material.

A similar analysis programme is also ongoing for the solar array retrieved from the Hubble Space Telescope (HST) in December 1993, after 3.62 years in an orbit of about 600 kilometers mean altitude. Due to the high operating altitude and extended dwell time, a larger number of impacts is observed on its total surface area of 62 square meters. The largest hole diameter is 2 to 3 millimeters.. As the flexible HST blankets have a total thickness of 710 microns, several impacts (2 to 4 per square meter) have completely penetrated the material. On the other hand, it appears that the HST array did not suffer any functional damage from the many impacts. The European Space Technology Centre, Netherlands (ESTEC) is currently developing a database to archive images and analysis results of impact features on the EURECA and HST surfaces. Results of these analyses will be used to validate the present reference flux models for small size meteoroids and space debris.

Examination of windows, radiator panels and other surfaces of the United States Space Shuttle orbiters show that environmental models underestimate the microdebris population and that this population is growing with time. While the NASA space debris damage model Bumper predicted 13 window replacements in 12 shuttle missions, the actual number of replacements was 19. The source of actual window damage (i.e. meteoroid or debris) was determined by scanning electron microscope analysis and compared to Bumper predictions, While micrometeoroid damage was predicted correctly (10 actual over 11 predicted), microdebris damage is underestimated more than three times (8 actual over 2 predicted).

B. Modelling of the Space Debris Environment and Technical Assessment

Models of the space debris population are needed to fill in gaps in existing measurement data, to interpret new data, and to project the characteristics of the future debris environment. There are two major classes of debris models in use today. Population characterization models take information about the orbital elements and other characteristics of space objects and convert them into measurable parameters such as flux, detection rate for an instrument, or collision velocity. More complex models are used to understand the future growth in the debris population. These model types are not entirely distinct; the output of a model of one type is often used as the input for a model of the other type.

A comparison of different space debris models with observations have been performed by a special working group of CNES. It is a first step of a three-step programme. The second step is an accurate risk analysis for space missions followed by the third step, proposals for space debris mitigation procedures. For "small" debris (below 10 centimeters), mathematical models should give the flux of particles for calibration with observations on-board spacecraft. For a more detailed comparison with observations, current detectors are not sufficient and a new generation of detectors is therefore proposed. The main reference model considered by CNES for space debris population is that of D. J. Kessler (NASA, Johnson Spaceflight Center, Houston, Texas) and for micrometeoroids, the model of E. Grün (Max-Planck Institute, Germany). The main inputs are the size of particles, altitude, inclination and date. Main outputs of these models are: the flux in orbit (number of impacts per square meter per year), consisting of micrometeoroids flux, debris flux and total flux. The total number of impacts also depends of course on the duration of the mission and the effective area of the spacecraft involved.

For comparison with models, the following data have been used: from the FRECOPA experiment (5.7 years in orbit) on the LDEF satellite, from the ARAGATZ mission (1 year in orbit) on the Mir space station, from the analysis of solar panels (11 months in orbit) of the EURECA platform and from the solar panel (3.6 years in orbit) of the HST observatory. The method of analysis consists of localization of the impacts, identification of the particle nature (debris or micrometeoroids), and conversion from the diameter of the crater to the size of the particle. Finally, the number of impacts as a function of particle diameter and histogram of frequencies (number of impacts per diameter class) led to the estimation of the cumulative flux which can be compared with model prediction.

In general, good accordance between model predictions and measurements has been found. There are some discrepancies for small particles of 10 to 100 micrometer in size as well as a slight underestimate of the model for the Mir station orbit. To improve the data sources, a new generation of detectors is prepared with low mass and energy consumption, but enabling estimation of instantaneous (not only cumulative) flux. The on-board recording of the time of impacts is also important for estimation of debris environment evolution as a function of time. Mock-ups of the new detectors are now tested in hypervelocity chamber and in a short time, new detectors should be available for use in different orbits (on Mir and SPOT 4 spacecraft).

Unique debris hazards associated with the proposed satellite constellations have been studied by the United Kingdom. A satellite constellation is a distributed architecture of satellites to provide global positioning, Earth observation, hand-held personal communications, messaging or data transfer. There are proposals for a large number of new systems, which means that over 1000 new satellites will be placed into high inclination orbits at altitudes between 700 and 800 kilometers and 1200 to 1400 kilometers within 4 to 6 years. Among the most advanced projects, the communication satellite constellation Iridium should consist of 77 satellites, Teledesic of 924, Globalstar of 48, Orbcomm of 26, etc. Realization of such projects will result in concentrations of satellite mass at certain regions of space around Earth.

To keep the constellation operational, frequent satellite replacement launches are envisioned. During the launch and deployment phase, there are usual problems associated with the explosion of launch vehicles or explosion and collision with fragments from un-passivated upper stage or with some non-tracked object. In addition, there is a possibility of collision with other satellites being deployed. At the operational orbit, additional hazards include collisions with uncontrolled constellation satellites, fragments from constellation satellite breakups or from launch vehicle breakups. Also de-orbiting of non-operational satellites should be planned so as to avoid collision with other satellites in the constellation.

The probability of collisions with debris within the constellation was modelled using different assumptions on the number of orbital planes and frequency of catastrophic collision breakups and explosion-induced breakups. It was found that there is a low probability of short-term collision cascading effect, but a high probability of cascades with background debris population. A careful selection of operational practices will be needed to guarantee long-term functioning of the proposed satellite constellations.

To acquire an unbiased technical assessment of the research needed to better understand the debris environment, the necessity and means of protecting spacecraft against the debris environment, and potential methods of reducing the debris hazard, NASA asked the National Research Council to form an international committee to examine the orbital debris issue. The committee was asked to draw upon available data and analyses to: (i) characterize the current debris environment; (ii) project how this environment might change in the absence of new measures to alleviate debris proliferation; (iii) examine on-going alleviation activities; (iv) explore measures to address the problem; and (v) develop recommendations on technical methods to address the problems of debris proliferation.

In the summer of 1993, the National Research Council formed a committee of eleven technical experts from six spacefaring nations to perform this task. In 1995, a report "Orbital Debris - A Technical Assessment" was published, representing the consensus view of the committee. The committee strove to ensure that the study focused on technical issues. This report does not suggest appropriate funding levels for future debris research, nor propose specific protective measures for particular spacecraft, nor lay out detailed implementation strategies for techniques to contain the future debris hazard. Decisions on such matters involve political and economic as well as technical considerations and must be made by entities capable of weighing all these factors. Rather, this report seeks to provide engineers, scientists, and policy makers with the sound technical information and advice upon which such decisions must be based.

C. The Use of Nuclear Power Sources in Outer Space

A numerical analysis related to possible collisions of NPS with space debris has been performed by the Russian Federation. The following contingencies have been examined in particular: destruction of the NPS structure, change of orbital parameters of NPS after collision, its entry into the atmosphere, and possible atmospheric destruction and fallout of radioactive toxic material particles and parts of the NPS structure. Collisions with space debris have been considered for reactors launched in the period 1970 - 1988 and injected into orbits within the 700 to 1000 altitude range. A typical reactor has a mass of 1250 kg, a diameter of 1.3 meters and a length of 5.7 meters incorporating fuel rod assembly and radiation shield. A fuel-element assembly of 53 kg contains 37 fuel rods, each with steel cladding, fuel pin of uranium-molybdenum alloy and axial reflectors of beryllium.

Collisions with space debris capable of considerable or catastrophic (e.g. 10 percent of mass) NPS damage down to small fragments and particles or creation of such velocity impulse that could lead to substantial change of orbital parameters and untimely re-entry from initial orbit were considered. For typical NPS orbits (altitude 930 to 970 kilometers, inclination of 65 degrees), the most probable relative velocity of collision is about 12 kilometers per second at an angle of collision of 108 degrees. Estimated probabilities of collision with space debris larger than 0.5 centimeters were computed for 250 years into the future using model distribution of debris as of 1994 and corresponding to the present rate of spacecraft launchings. The probability of collision is sufficiently high and reaches 1 in 55 years. For space debris more than 2 centimeters in diameter (capable of considerable NPS destruction), the collision probability should be lower and is subject to further computations.

Research on aerodynamic destruction of NPS and the fuel rod assembly during their descent into the atmosphere after collision at the initial re-entry trajectory (altitude 160 kilometers) has confirmed, that the NPS structure destructs in a range of altitude between 74 and 64 kilometers, the reactor and fuel rod assembly between 64 and 50 kilometers and reactor fuel pins (uranium - molybdenum alloy) down to particle dimensions of less than 1 millimeter in the range between 50 and 47 kilometers. Only partial destruction of the beryllium axial reflectors (melting of the external layer) occurs.

The fallout of millimeter size nuclear fuel particles, allowing for uranium fission product decay at the moment of collision, will not lead to a significant change in the radiation levels over the fall-out territory. The fall of beryllium reflector parts and partially failed radiation shield of lithium hydride may constitute a threat from the point of view of toxicity, which will prompt search and clean-up (removal) measures. The set of measures on the prediction of NPS re-entry orbital parameters, region of re-entry into dense layers of the atmosphere, territory of the fall-out of radioactive particles and NPS structure parts were developed by the Russian Federation earlier. They may be used in the event of detection of the collision between NPS and space debris. Similarly, inspection and control of radiation situation procedures on the fall-out territory, search, location and removal of fallen parts were applied in connection with NPS reactor launchings.

In the United Kingdom, studies continued on possible supplements to the Principles relevant to the use of nuclear power sources in outer space, adopted by the General Assembly on 14 December 1992. While this Resolution includes valuable consensus agreements on topics such as consultation, assistance to States affected by an accident, liability and compensation it suffers from a number of limitations. Among these are the exclusion of propulsion and extra-terrestrial bases; their formulation in terms of particular technologies; ignoring the potential effects of space debris; and inconsistencies with the more mature safety principles developed for the terrestrial applications of nuclear power. Therefore, a revision is suggested which generalizes the intentions embodied in Resolution 47/68 in a way which is consistent with subsequent international developments under the aegis of the International Commission on Radiological Protection (ICRP) and IAEA. The revision takes the form of six Supplementary Principles incorporating developments in probabilistic risk assessment, safety culture and radiological protection together with the recognition of the importance of safeguards. Subject to a consensus being reached on these Supplementary Principles and their associated numerical risk values (A/AC.105/C.1/L.203), this opens the way to eliminating the need for exceptions so that the revised principles are of universal applicability.

D. Remote Sensing Applications for Global Mapping and Environmental Monitoring

With the successful design, development, launch and in-orbit performance of the first generation of the Indian remote sensing satellite IRS, India is surging ahead to provide improved and enhanced data services from the second generation of remote sensing satellites, IRS-1C and 1D. IRS-1C, launched on 6 December 1995, is characterized by an improved spatial resolution, extended spectral bands, stereo viewing and faster re-visit capability. Besides cartographic applications, the IRS-1C mission mainly addresses the following areas:

- Crops and vegetation applications with specific reference to mixed crops and vegetation discrimination;

- Oceanographic applications, in particular observations of physical oceanographic parameters such as winds, sea surface temperature, waves, etc., and biological parameters;

- Atmospheric applications for monitoring global changes such as the depletion of the ozone layer over the Antarctic region.

The major elements of the IRS-1C mission, besides the spacecraft itself, are the Space Craft Control Centre, the Payload Data Reception Stations and the Data Products Generation Centre. IRS-1C operates in a circular, heliosynchronous, near polar orbit with an inclination of 98.69 degrees, at an altitude of 817 km in the descending node. IRS-1C needs approximately 100 minutes to orbit Earth, which means that the satellite completes 14 orbits each day. The entire surface of Earth is covered after 341 orbits during a 24 days cycle.

IRS-1C carries three imaging sensors which are characterized by enhanced resolution. The Panchromatic camera (PAN) has a spatial resolution of 5.8 meters, operates in the spectral range of 0.5 to 0.75 micrometers and employs three CCD devices of 4096 elements each. A multispectral Linear Imaging Self-Scanner (LISS-3) camera provides images with a spatial resolution of 23 m. This camera is also capable of producing images in the near infrared band (1.55 - 1.70 micrometers wave length). The Two-Band-Wide Field-Sensor (WiFS) operates in the visible and near-infrared region with a swath width of 810 km and resolution 190 meters.

Space research activities in Morocco, related to remote sensing and environmental monitoring, are characterized by an active, realistic and long-term policy at both the national level (coordination, information, training and project formulation) and the international level (participation in forums, international committees and bilateral and multilateral projects). The use of outer space in Morocco is becoming ever more developed, extensive and diversified.

With regard to satellite data, stations are currently in operation to receive METEOSAT weather satellite data, such as the National Department of Meteorology (DMN) station. There are plans to set up two NOAA stations, one for meteorological studies at the DMN and the other at the Royal Centre for Spaceborne Remote Sensing (CRTS) for receiving advanced very high resolution radiometer (AVHRR) data. This station is to be set up within the framework of the GLOVE project, which is co-financed by the European Union.

In the fields of data exchange and remote sensing networks, CRTS is coordinating Moroccan efforts to set up the Cooperation Information Network (COPINE) project launched by the United Nations Office for Outer Space Affairs. This project aims to establish satellite communication stations (INTELSAT) in a number of African countries enabling them to exchange data with each other and with European countries, particularly in the areas of the environment, natural resources and tele-medicine. The opening up of rural areas is a facet of the project of particular interest to national users.

A number of projects combining spaceborne remote sensing and geographic information systems (GIS) are in the process of development or implementation. These projects are designed to meet needs in the areas of natural resource inventory and management, environmental protection and town and country planning within the context of national and regional development programmes.

In the area of on-going training, CRTS has continued organizing short (one-week) and longer (two-week) courses to provide an introduction into the basic principles of spaceborne remote sensing, geographic information systems, and applications in areas of particular interest to the Kingdom of Morocco and the region. These courses, especially those relating to water resources, desertification, common grazing land and the management of fishery resources, are regularly attended by African participants in positions of responsibility.

GEOSPACE, a company located in Austria, is currently conducting a global mapping project to produce a digital atlas of the world. This global satellite image mapping project aims at developing a global geographic information system, which is easy to use, cost-effective and easily accessible for frequent updates. Studies are performed at the local, regional and international level.

The global mapping project, in particular has arisen due to recent regional and global environmental and economic changes, such as increasing pollution of land and water, dramatic population growth and changing consumption patterns. Such a project would be an essential contribution to sustainable development and the preservation of the environment. The project shall also play a vital role in the overall process of homogenizing spaceborne data, which would tremendously facilitate the timely provision of satellite derived information on the environment and natural resources.

The main benefits to be obtained through the global mapping project will be the availability of a cost-effective high resolution global geographic information system. Funding for the project shall be provided by national, regional and international organizations, and it is hoped that both the governmental and the private sector will contribute to the project.

The status of new commercial remote sensing satellites was reviewed by the Secretary General of ISPRS. These new satellites are intended to provide high resolution (up to 2 to 5 meters) data in the areas of meteorology, cartography, natural resources and commercial imaging. Countries who in the recent past have been involved in the development of such commercial remote sensing satellites are France, Germany, India, Japan, the Russian Federation and the United States. Furthermore, the European Space Agency plays a major role in the development of new remote sensing satellites.

An outlook for the next decade indicates that 99 Earth observation satellite payloads are planned to be implemented, out of which 57 payloads should be established within the next five years. These new payloads will play a significant role in developments towards digital photogrammetry and remote sensing.

Photogrammetry and remote sensing are the key ingredients in the spatial information sciences for monitoring Earth's environment, assessing and predicting natural disasters, thematic mapping, preservation of national and international security and sustainable development. In the near future, spacefaring nations will develop remote sensing satellites with spatial resolutions in the range of 1 meter.

In the context of accelerating economic and environmental development, a programme entitled "Resource 21" will be launched in the near future. Resource 21 is an information service company with the objective to improve agriculture, environment and natural resource monitoring. It is a market driven programme and combines satellite remote sensing, telecommunications and information systems technology. Resource 21 shall provide information products within hours of satellite data acquisition. It will also provide coverage of Earth every three days with a spatial resolution of 10 m. The system will be comprised of four satellites with a swath width of 205 km. Resource 21 should be operational in 1999.

A further system to be implemented in the near future is the geophysical and environmental Earth resource observation system (GEROS), aiming to provide timely and accurate information on agriculture, forestry and coastal zones. This system will be comprised of six satellites, the first of which is scheduled to be launched in 1998.

E. International Space University - Providing Education Programmes to Professionals

The International Space University (ISU), established in 1988, places emphasis on an interdisciplinary, international and intercultural space education programme. ISU is dedicated to the education and development of professionals in all disciplines (such as creators, innovators, managers and leaders) in space-related fields, the creation and expansion of knowledge through research, and the exchange and dissemination of knowledge and ideas. All of the above activities contribute to the development of space-related activities for peaceful purposes, the improvement of life on Earth and the education and inspiration of leaders and innovators who will guide humanity beyond the next frontier.

During the course of the summer session programmes of ISU, comprehensive lectures are provided in all space-related disciplines as well as discussions on how these disciplines can interact. Furthermore, an international space project is designed during the summer curriculum, resulting in a professional report with practical utility for the international space community. Overall, these summer curricula strengthen the development of professional skills and personal qualities required to design, implement, lead and manage major phases of space programmes.

The ISU summer session provides an intensive 10-week programme hosted at a different location each year. To date, nearly 1,000 students have participated in summer session programmes. In addition, 450 internationally recognized space experts (astronauts and cosmonauts, designers and engineers, space medical doctors, scientists, physicists, historians, policy makers, lawyers, managers, entrepreneurs, etc.) from 25 countries have contributed as lecturers since 1988.

During the summer curriculum, a series of core lectures are held, providing an introduction to basic concepts of the following disciplines: System Architecture & Mission Design; Business & Management; Engineering; Life Sciences; Policy & Law; Resources, Robotics & Manufacturing; Satellite Applications; Physical Sciences; Space & Society and Informatics. Following the core lectures, a series of themes and specialized lectures intends to deepen the knowledge in specific areas, containing contemporary and future issues.

In addition to the summer session programmes, ISU has recently launched a "Master of Space Studies" Programme, held at its Central Campus in Strasbourg, France. This one-year graduate level programme comprises three major elements: (a) Sciences and Applications, (b) Engineering, Systems and Technology, and (c) Management and Social Sciences.

F. Space Transportation

The Russian Federation continues the use of middle and heavy class launchers of the Soyuz, Molniya and Proton type to launch communication, scientific and many other payloads into different orbits (including GSO). In addition to the Russian national space transportation programme, these launchers are also used in furtherance of international cooperation. The Tsiklon and Zenit launchers are produced in cooperation with Ukraine. The most used cosmodrome in the world - Pleseck - is responsible for 60 percent of Russian launchings and for 10 percent worldwide. During the thirty years of its existence (since March 1966), there were almost 1,500 successful launchings. Plans are progressing for a possible gradual building of the new Russian cosmodrome at Svobodny (Amur region) in the eastern part of the country.

To prolong the exploitation cycle and improve ecological parameters, a small modernization of launchers is to be made by the year 2000. The modified Proton-M launcher has the capacity to carry 21,700 kg to LEO instead of the current 20,600 kg capacity. It will have an advanced guidance system, more powerful first stage engine as well as improved ecological parameters. Tests of the modified, ecologically clean version of the Soyuz launcher should start soon at the Pleseck cosmodrome under the name Rus. It will have new engines at all three stages and an improved guidance system. In addition, development of the perspective, ecologically clean two-stage launcher Angara is continuing. It is made up solely of Russian components and will be also launched from the Pleseck cosmodrome. It can deliver 25 metric tons of payload into a 200 kilometer LEO with 63 degrees inclination. All fluid components - oxygen, kerosene and hydrogen are non-toxic.

Converted military rockets Start-1 and the more powerful Start use solid fuel and will also be used in the space programme. Another converted military launcher, Rokot, can be launched from its underground silo. It will be used for launching of smaller payloads into low and middle orbits for purposes of the Russian national space programme and also for international cooperation efforts. The integrated operation system also includes a launching complex (based on the complex used for Kosmos launchers), a service complex (based on Tsiklon serving) and tracking and telemetry, transport etc.

The Russian space corporation Energiya, the Ukrainian research and production centre Yuzhnoe, the Boeing corporation of the United States and a Norwegian shipbuilding company, are cooperating in the form of an international consortium named Sea Launch on the preparation of commercial launchings from a sea-based platform near the equator.

Another project of interest is the aircraft-launched booster Burlak. It is a two-stage liquid fuel rocket that can deliver 500 kg payload into LEO. A detailed proposal is also being worked out for the Aerokosmos two-stage rocket that separates from the aircraft on a parachute. Other ideas being developed in this area include the light two-stage launchers, Kvant and Ricksha, the latter aiming to deliver about 5 metric ton of payload into LEO.

The Association of Space Explorers (ASE) presented the concept of the "X-Prize" - a prize of $10 million designed to promote private industry development of a reusable, single stage, sub-orbital vehicle capable of carrying three adults (300 kg) to an altitude of at least 100 kilometers above Earth. ASE believes that the X-Prize will stimulate public interest in space exploration and development, and lead to the capability to fly many people into space, a goal which ASE actively promotes. The spacecraft must be privately financed and privately built. It must be flown twice within a 14-day period. Each flight must carry at least one adult to a 100 kilometer minimum altitude, but it must be built with the capacity to carry a minimum of three adults. The second flight must demonstrate a low per-flight cost and vehicle reusability. Both crew and spaceship must return to Earth, "substantially unharmed", from both trips. Entrants must specify their take-off and landing location prior to the flight. The spacecraft must make a controlled landing within five kilometers of the chosen landing site. The X-Prize is international and open to anyone who abides by the rules.

G. Astronomy and Planetary Exploration

In early 1995, the international astronomical community was dismayed by the publication of a proposal on behalf of UNESCO, to mark its 50th anniversary by the launch of a solar reflector - the "Star of Tolerance". It was to have been in the form of a double star comprised of two reflecting balloons, one of 50 meters and the other of 30 meters in diameter connected by a 2 kilometer tether. The Star would transmit radio messages and, with the right receivers, be able to activate additional ground based events such as switching on floodlighting of buildings, etc. It would appear as bright as the star Sirius, or even as the planet Jupiter, orbit the Earth every two hours at a height of 1250 kilometers. Its visibility would be confined to the twilight sky. It was suggested that after four years in orbit, the "Star" would have its orbit lowered in order to re-enter the atmosphere. The "Star" itself would not be a disaster for astronomy, even though it would be a significant hazard. What did cause major concern within the astronomical community was the precedent it would set, if implemented. It would be a clear signal, that it was culturally, scientifically and educationally acceptable to use spaceborne solar reflectors to convey messages on an international scale.

But development may not stop with solar reflectors - they are of limited usefulness for advertising because their brightness is limited by the efficiency of reflecting sunlight. The existence of such a fundamental limit, diluted by the inverse square law, reflection inefficiency and atmospheric extinction, seems to be recognized already. In 1994, SKY TV announced that it was considering space projection of its logo as a hologram produced by spaceborne lasers. In this situation, there is no limitation of visibility close to twilight and the energy expended is only bounded by engineering and financial constrains. Were such schemes demonstrably feasible (SKY TV based its suggestion on a NASA authority that stated that it was possible), then multiple space holograms would ensure not just the demise of deep sky astronomical imaging, but the whole of astronomical observation at optical wavelengths.

In the field of radio astronomy, there are problems with artificial radio transmissions from orbiting satellites. The interference caused by the GLONASS (Global Navigation Satellite System) at 1612 MHz has been resolved recently. Thus the conditions for observing the important OH maser line at that frequency should rapidly improve. However, the newly proposed satellite communication system Iridium is again threatening radio astronomical use of that band. The down link frequency from the satellites at 1620 MHz will be adjacent to the reserved radio astronomy band at 1610.6 to 1613.8 MHz. Since commercial transmissions must use higher power and astronomy is endeavouring to detect a weak cosmic signal, the possible spill of artificial transmission could mimic emissions from radio galaxies. Although Iridium and the United States National Radio Astronomy Observatory have reached a Memorandum of Understanding, the remainder of the radio astronomical community, with good reason, regards that bilateral agreement as a very poor basis for the future. What is needed is some kind of operational mandate which would allow astronomy, civilization, industry and commerce to coexist.

Another mobile communication project, Teledesic, is looking for an allocation of frequency in the hitherto non-allocated millimeter wavelength, very high frequency range in the 19 to 29 GHz band. This spectral region is one of peculiar importance to radio astronomy since there are many interstellar line emissions. It is subject to absorption (mostly by water vapour) so that there are only a limited number of transparent windows at these frequencies. Satellite up and down links must use these windows for commercial exploitation, and radio astronomy needs them to detect the faint interstellar spectrum lines emitted by a wide range of molecular species. Such studies contribute to understanding the structure and evolution of our own and other galaxies, formation of stars and planetary systems and, possibly, the development of life. The detection of these signatures of the nature of cosmic chemistry will be of crucial importance in discerning how large chemical molecules can be constructed and where in the Universe such processes take place. Very great care will have to be exercised in assigning the millimeter frequency range for communications if access to such far reaching astronomical information is to be maintained.

In addition, mobile multi-satellite systems, like Iridium, Teledesic and others, are demanding very large numbers of satellites in LEO. These satellites will reflect sunlight and exacerbate the worsening space debris problem. A study of the United Kingdom Schmidt Archive at the Royal Observatory Edinburgh has shown that satellite trailings on precious astronomic plates has increased from 1.5 trails per hour of exposure in 1978 to 2.5 in 1994. More deep sky imaging and photometry will be degraded as a consequence when such projects become operational. Clearly, systematic thought is urgently needed to minimize the impact on both radio and optical astronomy. Attention should be given to restoration of astronomic observing conditions to a state where the hazards are as close to natural limitations as may yet be practicable. Above all, no activity of itself should be permitted which would terminate unilaterally major techniques for obtaining astronomical information and data.

The International Conference on Near-Earth Objects was held in New York on 24 to 26 April 1995. It was co-sponsored by the Explorers Club, the Planetary Society and the United Nations. The subject of the conference, Near-Earth Objects (NEO), was comets and asteroids whose orbits could intersect the orbit of the Earth around the Sun. The possibility of collision between the Earth and NEO has been the subject of much speculation regarding the likelihood and consequences of such an event. Since it has been generally understood that the impact of a kilometer size NEO would have severe consequences on the terrestrial biosphere, it is of some interest to estimate its probability. Astronomy and planetary science have shown that craters are an ubiquitous, if not dominant, feature on planets, moons and asteroids within the inner solar system. Detailed studies of cratering records indicate that the impact of a kilometer or greater sized NEO was a regular occurrence, with continuity over large times scales. The fossil records appear to suggest that our own progression from mammalian ancestors was assisted by a NEO impact that eliminated a vast number of species, including, at the cretaceous tertiary boundary (K/T), the predator dinosaurs.

The main focus of NEO research at this time should be towards generating more knowledge about the origin, evolution, and dynamical and material characteristics of asteroids and comets that can interact within Earth's immediate space environment. The heightened public awareness about NEO and hazards associated with possible impacts must be met with a responsible explanation based on scientific knowledge. From this perspective, NEO research is an opportunity to pursue interdisciplinary scientific research in the basic space sciences through international cooperation. Of prime operational importance is the creation and maintenance of an internationally organized NEO catalog and ephemeris (predictions) computation service. To this end, improved observational data are needed from both northern and southern hemispheres, especially for NEO under one kilometer diameter.

To underscore the importance of these observations and the uncertainty in determining a value, albeit approximate, for the probability of collision with the Earth, an analysis of the Earth crossing asteroid (Apollo, Amok, and Athens families) and comet (Jupiter and Halley families) statistics was carried out. It is suggested that the overall collision probability may be uncertain by a factor as large as five. This is primarily due to the relatively large number of smaller objects (below 200 meters) and the fact that only a very small percentage of this population has been discovered. To determine this population more accurately, observations must be extended to higher magnitude ranges and spectral classes wherever possible.

Obtaining an accurate number for the comet population does not appear to be so straightforward, since a determination of the ratio of passive to active comets proved to be extremely difficult. Therefore, further NEO studies should center around extensive and detailed observational work, from which modelling and other assessments could follow. Until this empirically based research is carried out, it will not be possible to realistically characterize the NEO threat, nor will the likelihood of a successful outcome from NEO countermeasures be assured in any way.

Appendix

LIST OF SCIENTIFIC AND TECHNICAL PRESENTATIONS

I. SYMPOSIUM ON UTILIZATION OF MICRO- AND SMALL SATELLITES FOR THE EXPANSION OF LOW-COST SPACE ACTIVITIES, TAKING INTO PARTICULAR ACCOUNT THE SPECIAL NEEDS OF DEVELOPING COUNTRIES, ORGANIZED BY COSPAR AND IAF

The first session of the symposium, entitled "Small satellite activities", was co-chaired by Mr. K. Doetsch, representing IAF, and Mr. W. Riedler, representing COSPAR. The second session of the symposium, entitled "The potential of micro- and small satellites", was co-chaired by Mr. J. Ortner, representing IAF, and Mr. K. Szegö, representing COSPAR. Mr. S. Grahn of COSPAR was the Rapporteur for both sessions of the symposium.

"Small Satellite Programmes in Developing Countries (Keynote Address)," Mr. P. Molette, Chairman of the Subcommittee on Small Satellites for Developing Nations, International Academy of Astronautics (IAA).

"The European Space Agency's Small Missions Opportunities (SMO) Initiative," Mr. F. Ongaro, Strategy Office, European Space Agency.

"Small Satellite Projects in Latin America," Mr. C. Puebla Menne, Comité de Asuntos Espaciales de Chile, Chile.

"An Introduction to KITSAT Program," Mr. S. Kim, Deputy Project Manager, Satellite Technology Research Center, Korea Advanced Institute of Science and Technology, Republic of Korea.

"Small Satellite Projects in Spain," Mr. A. Giménez, Director General, Instituto Nacional de Técnica Aeroespacial (INTA), Spain.

"Contribution of Small and Micro-Satellites to Scientific Research (Keynote Address)," Mr. K. R. Sridharamurthy, Indian Space Research Organization (ISRO), India.

"French Experience and Prospects in the Use of Small and Micro-Satellites for Space Science and Applications," Mr. P. L. Contreras, System Division Head, Toulouse Space Center, Centre National d'Etudes Spatiales (CNES), France.

"NASA Cooperation with Developing Nations on Small Satellite Programs," Mr. J. Mansfield, Associate Administrator, Office of Space Access and Technology, National Aeronautics and Space Administration (NASA), United States.

"Brazilian Small Satellite Program and its Particularities on Space Needs," Mr. D. Ceballos, Instituto Nacional de Pesquisas Espaciais (INPE), Brazil.

"The Sunset Project," Mr. S. Mostert, University of Stellenbosch, Republic of South Africa.

"Summary of the Symposium," Mr. S. Grahn, COSPAR.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

"Space Debris Related Research at the Research Establishment for Applied Sciences (FGAN)," Mr. D. Mehrholz, FGAN, Bonn, Germany.

"Measurements of the Orbital Debris Environment," Mr. A. Potter, National Aeronautics and Space Administration (NASA), United States.

"Modelization of Space Debris and Comparison with Observations, Mr. F. Alby, Centre National d'Etudes Spatiales (CNES), Toulouse, France.

"Space Debris Research in ESA," Mr. W. Flury, ESOC, European Space Agency.

"Summary of the United States National Research Council Report on Orbital Debris: A Technical Assessment," Mr. G. Levin, National Aeronautics and Space Administration (NASA), United States.

"The Unique Debris Hazards Associated with Satellite Constellations," Mr. R. Crowther, Defence Research Agency, Farnborough, United Kingdom.

"Collision of Nuclear Power Sources with Space Debris," Mr. V. S. Nikolaev, Ministry of Atomic Energy of the Russian Federation.

"Interpretation and Development of the Safety Principles for Nuclear Power Sources in Space," Mr. B. Wade, AEA Technology, United Kingdom.

"Russian Space Transportation System," Mr. A. V. Yakovenko, Ministry of Foreign Affairs, Russian Federation.

"X-Prize: Development of a Reusable, Single-stage, Sub-orbital Vehicle," Mr. D. Prunariu, cosmonaut, Association of Space Explorers (ASE).

"ISU Design Projects on Small Satellite for Earth Observation for Polar Regions," Ms. L. Stojak, International Space University (ISU).

"Application Potential of Indian Remote Sensing satellite (IRS-1C)," Mr. R. R. Navalgund, Space Applications Centre, Ahmedabad, India.

"Applications of Remote Sensing in Cartography and Mapping," Mr. M. Saoud, Responsable technique (CRTS), Morocco.

"Status of New Commercial Remote Sensing Satellites: High Resolution Imaging Systems," Mr. L. W. Fritz, International Society for Photogrammetry and Remote Sensing (ISPRS).

"Geospace Global Mapping Project and the Digital Atlas of the World," Mr. L. Beckel, Geospace, Austria.

"Central European Satellite for Advanced Research (CESAR)," Mr. Z. Klos, Polish Academy of Sciences, Warsaw, Poland.

"Cooperation on Small Satellites," Mr. Y. B. Zoubarev, State Scientific Research Institute of Radio, Russian Federation.

"Solar Reflectors, Radio Astronomy and Access to the Sky," Mr. D. McNally, International Astronomical Union (IAU).

"Report on the International Conference on Near-Earth Objects," Mr. J. Remo, Organizer.