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USER DEFINITION AND MISSION REQUIREMENTS FOR UNMANNED AIRBORNE PLATFORMS (Revised)

by

M. B. Kuhner and J. R. McDowell

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Approved by:

D. S. Edgecombe, Section Manager

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

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PREFACE

The study reported herein was carried out by Battelle's Columbus Laboratories for the NASA Wallops Flight Center under NASA Contract No. NAS6-2938. This report describes the approach taken and the results of the 6-month study. The work was done under the general supervision of Dr. A. C. Robinson, Battelle's manager for the contract.

Battelle would like to acknowledge the efforts of Harvey C. Needleman of the Wallops Flight Center who was the technical monitor for this study.

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INTRODUCTION

The scientific and application experiment user community has a continuing need for economic and effective airborne measurement platforms. Although there are a variety of existing unmanned platforms used for airborne measurements, new platforms could augment and enhance existing capabilities and could provide greater options to the users. NASA Wallops Flight Center (WFC) has proposed five strawman unmanned airborne platforms for the consideration of the user community as potential new vehicles. These proposed strawmen provide a spectrum of measurement platform capabilities supporting associated mission tradeoffs such as payload weight, operating altitude, range, duration, flight profile control, deployment flexibility, quick response, and recoverability. The physical characteristics and performance capabilities of these strawmen are not arbitrary; they are based on existing prototype systems or concepts which have been studied. The five strawman platforms are:

- A small unmanned airplane, similar to NASA's Mini-Sniffer*, which has the potential to carry a 25- to 70-lb payload up to a maximum altitude of 100,000 ft for a maximum duration of 3 hours. The Mini-Sniffer was initially developed as an atmospheric survey aircraft for sensing turbulence and measuring atmospheric constituents. This remotely piloted vehicle (RPV) may represent a cost-effective solution to the problem of combining the flexibility and longer range features of aircraft operation with the altitude advantages of balloons.

* Dryden Flight Research Center has had prime responsibility for systems development.

- A small unmanned mini-blimp which could carry a 90 to 130-lb payload up to a 2000-ft altitude for a flight duration of 18 hours. The mini-blimp concept, similar to a small, unmanned version of a Goodyear blimp, could fly as fast as 60 mph or hover stationary over a desired ground position.
- A free flight balloon, deployed in mid-air by an airplane, which could have a 50 to 500-lb payload capability at mission altitudes from 70,000 to 90,000 ft. A zero-pressure design would provide mission durations of from 24 to 72 hours. A super-pressure design would provide a mission duration of 30 days or greater. Advantages of the mid-air deployed balloon (MADB) include a capability for quick reaction to events of special scientific interest and a capability for deployment over remote or impassible regions.
- A tethered balloon which could lift a 4000 to 8000-lb payload up to 15,000 ft, with a mission duration of 7 days. This lighter-than-air system provides a low altitude stationkeeping measurement platform for extended duration missions.
- A High Altitude Powered Platform (HAPP) concept which could maintain station over a fixed ground point at an altitude of 70,000 ft, carrying a payload of 1600 lb or more. The HAPP, powered by a microwave beam from the ground, could remain on station up to one year. The HAPP is presently in the early conceptual stages which have included technical feasibility and potential application studies. The concept is potentially well suited to missions requiring high repetition rate sampling over extended periods of time.

The primary purpose of this study was to survey and assess the airborne measurement requirements of the scientific and applications experiment user community, with respect to the suitability of the above proposed strawman platforms, and to identify new platform technology opportunities. Relative cost implications or comparisions were not required in the study. The results of the study are intended to assist NASA in determining whether the development of new platforms is warranted and in determining platform system requirements as well as research and technology needs.

The overall study effort consisted of two major tasks - the survey of the user community and, subsequently, the assessment of the survey results. The survey was intended to establish the data base for the assessment. An interim report was provided to NASA/WFC on 15 February 1979 to document the results of the survey. Subsequent to the issuance of that report additional responses have been received, evaluated and added to the data base for the assessment task. This final report, therefore, describes the final results of the survey and the assessment of the survey responses (individually and collectively) with regard to the user community's requirements and the suitability of the proposed strawman platforms to meet those requirements. In order to provide complete continuity and understanding in a single study report, this final report includes a description of the overall study approach and survey methodology and sampling strategy used which were orginally described in the interim report.

SURVEY APPROACH

The survey to assess the requirements for the suitability of the proposed platforms was aimed at contacting a representative sample of the scientific and application experiment user community. A top-down approach was used to initially structure and then to subsequently carry out the survey. Initially, contacts were made with key personnel involved in research advisory and policy-making roles in organizations encompassing research and applications dependent upon airborne measurement and surveillance platforms. Contacts, by meetings and telephone, were made with persons at NASA Headquarters (OSS, OSTA and OAST), DOD, DOE, EPA, NSF, NOAA, NCAR, and the U. S. Coast Guard. In addition, meetings were held with the National Academy of Sciences (Space Sciences Board and the Space Applications Board) and members of the U.S. House Space Science and Applications Subcommittee. All of these initial contacts were made to solicit recommendations as to how to structure the planned survey within their organizations by identifying key offices and individuals. They were also asked to identify other organizations and individuals engaged in scientific research and applications likely to require platforms similar to those proposed. These initial contacts have been documented in a series of study project memoranda which have been provided to WFC. The memoranda are:

BCL-UAP-ICM-78-1, "Possible Users of Advanced Airborne Measurement Platforms".
BCL-UAP-ICM-78-2, "Unmanned Airborne Platform Study Astrophysics Balloon Users".
BCL-UAP-ICM-78-3, "Unmanned Airborne Platform Study, Candidates for Survey in U.S. Coast Guard".
BCL-UAP-ICM-78-4, "Telephone Contacts Relative to Potential Candidates for UAP Survey".
BCL-UAP-ICM-78-5, "Telecon with Major John Dunkle, AF/RDSD, Pentagon, Washington, D. C." (Project Skyhook).
BCL-UAP-ICM-78-6, "Astronomer Candidates for UAP Survey".
BCL-UAP-MM-78-3, "Unmanned Airborne Platform Study, Meetings in Washington, D. C., October 16-18, 1978".
BCL-UAP-MM-78-5, "Unmanned Airborne Platform Study, Meetings in Denver/Boulder, Colorado, October 24-26, 1978".
BCL-UAP-MM-78-6, "Meeting with NASA/OAST on UAP Survey".

Recommendations of these initial contacts were followed through and the offices, individuals and other organizations which had been identified were contacted, primarily by telephone, to solicit the names of scientific/application experimenters considered by their peers to be in the forefront of their respective disciplines, currently using airborne measurement techniques and likely to use the proposed platform capabilities. Every lead was followed through until an individual was contacted who, in fact, could be considered qualified as a representative of the scientific/applications experiment user community. Most of those contacted in this manner were very cooperative and agreed to participate in the survey as potential platform users. During this process Battelle also came across many individuals who could be classified as research managers rather than active experimenters. A number of those managers have been included in the survey because their respective positions give them a somewhat broader outlook than researchers involved with highly specialized experiments.

One other technique was used to identify potential users and survey participants. An announcement of the survey was prepared and published in the Commerce Business Daily (CBD) requesting individuals to contact Battelle if they were likely users of the proposed platforms. This activity resulted in three individuals who qualified as potential users and agreed to participate in the survey.

Battelle has, by the process described, compiled an extensive list of potential users of the proposed unmanned airborne platforms. The list of these individuals and their organization affiliation is included in Appendix A of this report. Each individual listed agreed to participate in the study survey and, upon receipt of an information package, to supply Battelle with information on their future requirements for measurement platforms and an assessment of the suitability of the proposed platforms to satisfy those requirements. The list in Appendix A groups the survey participants in one of three broad discipline categories: atmospheric science (chemistry, physics and pollution monitoring); remote sensing of the Earth's surface; and astrophysics.

It should be noted that Battelle's objective in implementing the survey task of this study has not been to identify the largest possible number of potential platform users, but instead has been to identify a representative group who are judged by knowledgeable people in their respective fields to be those who can provide the most realistic and representive information on future requirements. Therefore, those individuals participating in the survey are considered to be an accurate representative sample of the experiment sector of the user community and are qualified, through their response in the survey, to help evaluate the projected effectiveness of the proposed platforms in terms of matching their research and applications requirements.

The top-down approach followed by Battelle in the survey task identified another category of survey candidates not considered to be platform users. Several individuals and organizations were identified who are, in practice, operators or providers of platforms. It was decided that key personnel in this category should be included in the survey to provide a different insight into future platform needs. A total of 16 of those individuals/organizations agreed to participate in the survey, and they are listed separately in Appendix A. It should be noted that the responses from these individuals have, primarily, provided some relevant background, but have not been included in the data base derived from potential users nor in the assessment of those data.

A copy of the information package and letter of transmittal sent to each survey participant is included in Appendix B of this report. The information package consisted of a brief description of the proposed strawman platforms and an accompanying information form to be filled out by the survey participant and returned to Battelle.

SUMMARY OF SURVEY RESULTS

Survey Participation

A total of 107 potential users initially agreed to participate in the survey and were subsequently provided with an information package on the strawman platforms. Of these, 58 returned written replies and one responded by telephone. Eight more have informed Battelle that they would not respond. Of these eight, three said they have no need for such platforms, one said that he was a planner rather than a user and so not qualified to respond, and the rest said that their responses would duplicate those of other participants. The remaining forty people informed Battelle that they would reply but their responses were not received by the time this report was completed. The responses from the platform operators or providers are not included in the summary. For purposes of analysis, the participants were initially divided into three broad discipline categories: atmospheric science, astrophysics, and remote sensing of the Earth's surface. In general, these categories represent measurement platform users whose directions of viewing interest are horizontal, up, and down, respectively. Table 1 shows a breakdown of the results received in these three categories.

TABLE 1. SUMMARY OF SURVEY PARTICIPATION

	Atmospheric Science	Astro-physics	Remote Sensing	Total
Number of people who agreed to participate	48	21	38	107
Number who responded	26	14	19	59
Number who informed Battelle they would not respond	3	1	4	8

The table shows that there is considerable variation in the numbers of people initially contacted in each of the three user categories. There are logical reasons for this. The atmospheric science group is very diverse. It includes users in the applied sciences making observations of pollution and meteorological phenomena. It also includes users in the pure sciences interested in the general chemical and physical makeup of the atmosphere as a whole. There is also great diversity in requirements. Atmospheric science users are interested in altitudes ranging from near the surface to 150 km. Furthermore, funding sources include many different organizations such as NASA, the NSF (directly and through NCAR), the EPA, the Army, Navy and Air Force, NOAA and others. Because of the diversity of this community it was necessary to contact a large number of people to insure that all areas were represented.

The astrophysics community is much less diverse than the atmospheric science community. A very large fraction of airborne astronomy and astrophysics is funded by NASA. The altitude requirements for the various disciplines within astrophysics are fairly clear cut and well known. Infrared and cosmic ray studies can be done on the surface or at a variety of altitudes depending on the nature of the specific experiment. Gammy-ray and hard X-ray astronomy requires very high altitudes and soft X-ray astronomy, higher still (soft X-ray observations are done from rockets or satellites). Virtually all optical (i.e., visible light) astronomy and radio astronomy is currently being done on the ground. By consulting with Dr. Jeffrey Rosendhal, who is Manager of Advanced Program Planning for the astrophysics division of NASA's Office of Space Science, it has been possible to pinpoint a select group of astrophysicists who are representative of those most likely to have requirements for the platforms under consideration. Dr. Rosendhal gave Battelle twelve names. These people suggested others, and the final number contacted was 21.

The community of users who do remote sensing of the Earth's surface is quite diverse in terms of funding sources and applications, but not so diverse insofar as requirements are concerned. They virtually all require mobile, controllable platforms such as airplanes or helicopters. Beyond this their basic need is for the least expensive platform that can carry their particular payload. For the most part, variations in altitude requirements are actually reflections of cost requirements. The fundamental measure of cost is dollars per unit ground area covered. Low altitude platforms tend to be inexpensive in terms of dollars per hour and so are preferred when only a small area needs to be covered. High flying aircraft tend to be expensive in terms of dollars per hour but, because they can cover a large area in a short time, the real cost in terms of dollars per square mile may be smaller than for low flying aircraft. Since the remote sensing community is diverse in one sense (applications) but fairly uniform in another (basic requirements), the appropriate number of people to represent this category of users was judged to be somewhere between the numbers required for atmospheric science and astrophysics.

Survey Response

The questionnaire sent to each survey participant was divided into three main sections. Part A asked for the participants' name, address, and telephone number. Part B was a series of questions to be answered with brief sentences or paragraphs on the users' general requirements. Part C asked for specific technical requirements for an experiment that the participant might carry out using one of the strawmen or some similar future platform. Tables 2, 3 and 4 summarize the results received on the questionnaire from the atmospheric sciences, astrophysics and remote sensing users, respectively. The tables give all the information from Part C and a capsule summary of the comments received under Part B. The first column of each table gives an identification number for each respondent. The purpose of this number is to provide a cross-reference with Figures 1-8, (to be discussed later). The next two columns give the respondent's name, organization and discipline. The next column indicates the payload or experiment which leads to the set of platform requirements listed in the central seven columns of the tables. The first three of these columns give the altitude in feet, the anticipated payload weight and ground travel distance in miles in the format "desired (min-max)". For example, under altitude, 2000 (1000-4000) means the desired altitude is 2000 ft but a range of altitudes from 1000 to 4000 ft would be acceptable. Similarly, the desired payload weight is shown as well as the minimum and maximum weights possible. The next column gives endurance in days in the format "desired/minimum" (e.g., 30/1 means a desired endurance of 30 days with an acceptable minimum of one day.) Where required endurance is less than one day, it is given in hours and so labeled. The next column gives the payload dimensions in inches. Next is displayed payload power requirements in watts in the format "average power/peak power". It turns out that this requirement rarely affects the platform, however, as most users indicated that their payloads would have self-contained power supplies. The final column of numerical data gives the required platform availability date for the experiment in question in the format "desired year/latest useful year". Where the participant indicated an interest in one or more specific strawman platforms, his preference is indicated in the next to last column. The final column gives a very brief capsule summary of some of the key comments made by each participant in Part B of the questionnaire or under the section labeled "your comments" on the last page of the questionnaire. These capsule summaries are provided for quick reference. A more complete discussion of the comments is given in the assessment portion of this report.

The response of the potential unmanned airborne measurement platform user community to the requirements and suitability assessment survey conducted represented an approximate 60% return. Based upon Battelle's experience in conducting technical surveys of this kind, this percentage of response to a mailed information package requesting a return of a questionnaire is considered high. The survey response, summarized in Tables 2, 3 and 4, therefore, formed the data base for the evaluation of the proposed strawman platforms.

TABLE 2. SUMMARY OF RESULTS FOR ATMOSPHERIC SCIENCE

Number	Person (Organization)	Discipline	Payload or Experiment Description	Altitude, (feet) Desired/ (Min-Max)	Payload Weight, (pounds) Desired/ (Min-Max)	Ground Travel Distance, (miles) Desired/ Minimum	Endurance, (days) Desired/ Minimum	Payload Dimensions, (inches)	Power Required, (watts) Average/ Peak	Platform Availability, (years) Desired/ Latest	Strawman Platform Preferred	Comments
1	B. D. Zak (Sandia Labs)	Environmental Research	Environmental monitoring system	2000 (1000–4000)	1000 (500–1000)	1000/500	4/2	48 x 60 x 84	300/--	79/--	Mini-blimp with larger payload	"The mini-blimp and tethered balloon are of most interest."
2	E. L. Martinez (EPA)	Air Pollution Field Studies	Photochemical pollution monitoring equipment	2000 (500–4000)	300 (150–500)	100/30	3/1	50 x 30 x 20	--	80/--	--	Need platforms which are more flexible and less costly than currently available. Some of the strawmen look promising.
3	C. Fitzsimmons (for E. David Hinkley) (EPA)	Ambient Air Quality Monitoring	Air quality monitoring equipment	500 (0–2000)	1000 (500–2000)	100/0	30/1	48 x 48 x 24	1000/2000	79/83	Tethered balloon	Aircraft use over city is limited for safety reasons. If tethered balloons less than $200/flight hour they would be useful.
4	Donald Stedman (U. of Michigan)	Atmospheric Chemistry	Power plant plume monitoring equipment	0–5000	60–200	60/20	12 hr/3 hr	30 x 30 x 80	1000/--	79/--	Mini-blimp (also HAPP & RPV)	The mini-blimp would be valuable for "low-altitude power plant plume studies, especially at night." The HAPP would be useful for "studies of very slow photolysis rates." "The RPV would be very good for vertical profiles of chemicals." The HAPP for long duration low stratosphere studies" using IR spectrometers. "I believe the mini-blimp would well be an entity with which NASA Wallops could provide an entirely new dimension in in-situ plume measurements. I mean to pursue this further."
5	James Armstrong (Denver Research Institute, U. of Denver)	Monitoring Airborne Gaseous and Particulate Pollutants	Plume monitoring equipment	750 (500–5000)	200 (50–500)	20/1	1/1	48 x 48 x 36	1000/--	80/--	Mini-blimp	"The mini-blimp could allow real-time in-situ particle and gas sampling to be conducted at locations and with mobility not possible using current airborne sampling techniques which include aircraft and tethered ballons."
6	Hans Rudolph (NASA-KSC)	Tropospheric Air/Rain Monitoring	In-situ monitor for O_3 and HCl	3000 (1000–5000)	100–200	50/50	3 hr	10 x 12 x 12	50/--	79/79	Tethered balloon	"We were gearing up to use a tethered balloon for in-situ sampling of O_3 and HCl . . . Program was halted because FAA would not authorize tethered balloon for long periods at KSC."
7	G. Gregory (NASA-LaRC)	Air Pollution Research	Air quality monitor	2000 (500–4000)	350 (200–600)	350/100	72 hr/8 hr	--	--	81/--	Mini-blimp	"It is desirable . . . to locate an instrument in an air parcel and maintain it [there] as it moves through an area." Mini-blimp's controllability a big advantage for this.
8	Harold N. Ballard (Army Atmospheric Sciences Lab)	Research Physicist	Atmospheric data monitoring equipment	0–30,000	15–23	5/1	3 hr/1 hr	4 x 14 x 12	--/140	79/--	RPV similar to mini-sniffer	The U.S. Army Atmospheric Sciences Lab "is presently developing . . . an RPV . . . to gather atmospheric data." It will be a "relatively low cost maneuverable atmospheric probe."

TABLE 2. (Continued)

Number	Person (Organization)	Discipline	Payload or Experiment Description	Altitude, (feet) Desired/ (Min-Max)	Payload Weight, (pounds) Desired/ (Min-Max)	Ground Travel Distance, (miles) Desired/ Minimum	Endurance, (days) Desired/ Minimum	Payload Dimensions, (inches)	Power Required, (watts) Average/ Peak	Platform Availability, (years) Desired/ Latest	Strawman Platform Preferred	Comments
9	Crofton Farmer (Caltech)	Atmospheric Remote Sensing	High res. interferometric spectrometers and grating radiometers for measurement of trace constituents	60,000	1000 (400–1000)	1000/100	[illegible]/2	36 x 48 x 24	300/350	80/84	--	"The greatest need [in my field is] to reach higher altitudes than currently attainable by balloons."
10	Konrad Mauersberger (U. of Minnesota)	Atmospheric Physics	Neutral mass spectrometer to measure H_2O, CO_2, O_3, SO_2, hydrocarbons, etc.	65 K – 140 K	30[illegible] ([illegible]0–[illegible]0)	0	0.3/--	33 in sphere	15/--	80/?	--	"My present experiment requires altitudes between 65,000 and 140,000 feet." The proposed platforms are generally limited to 70,000 ft, but the "experiment could be changed to accommodate the platforms."
11	James M. Rosen (U. of Wyoming)	Stratospheric Aerosols	Stratospheric aerosol monitor	66 (59–72) K	100 (25–100)	50/0	365/180	14 x 14 x 42	5/50	80/--	MADB Mini-sniffer HAPP	"Continuous measurements from HAPP would allow me to conduct experiments otherwise impossible. The mini-sniffer is probably most suitable [of the strawmen]."
12	Neil Farlow (NASA-ARC)	Aerosol Collection & Analysis in Stratosphere	Stratospheric aerosol collector	40–100 K	25 (3–25)	Short distance	Few hours	4 x 4 x 4	25/50	80/82	Mini-sniffer (small MADB would also be useful to him)	Only certain locations are available for A/C and balloon deployment. If mini-sniffer could be launched at remote locations it would be very useful.
13	L. R. Megill (Utah State U.)	Atmospheric & Space Science	--	70–150 K	100	0	10–30	--	--	--	--	Current interests are at 100–200 K ft. But if vehicle cheap enough could do mesoscale experiments at 70,000 ft. "I like the mini-sniffer."
14	D. J. Hofmann (U. of Wyoming)	Strat. Aerosols, Ozone, Atmos. Electricity	Small particle detector	60 (50–70) K	30	Vertical profile needed	3 hours	12 x 12 x 30	--	--	MADP	"A mid-air deployed system for light payloads (25 lb) would be useful."
15	I. C. Poppoff (NASA-ARC)	Stratospheric Research	--	--	--	--	--	--	--	--	--	The low altitude platforms don't reach stratosphere. The HAPP would be too expensive. The mini-sniffer doesn't carry enough and probably can't get to 100 K ft anyway.
16a	M. Shumate (JPL)	Remote Sensing of Atmosphere Using Lasers	Tropospheric ozone instrument	20 (6–50) K	700 (700–1000)	1000/100	<1	36 x 36 x 60	750/1500	79/82	--	These platforms would allow us to do "nothing we cannot already do."
16b	M. Shumate (JPL)		Stratospheric molecule radiometer	120 (110–550) K	350	0	1	24 x 24 x 40	280/300	79/82	--	--
17	Arthur Schmeltekopf (NOAA)	Atmospheric Physics & Chemistry	--	--	--	--	--	--	--	--	MADB	The new method we desire most is a "good safe balloon launching technique from remote locations." "The MADB would help but it will be much more expensive."
18	Stamatios Krimigis (Johns Hopkins)	Space Physics	--	80–500 K	--	--	--	--	--	--	--	"The altitude range of greatest interest in upper atmospheric physics is 25 km to 150 km, i.e., above typical balloon altitudes and below typical satellite orbits. Rocket observations are too brief in the 25 to 150 km range. Long term observations are necessary."

TABLE 2. (Continued)

Number	Person (Organization)	Discipline	Payload or Experiment Description	Altitude, (feet) Desired/ (Min–Max)	Payload Weight, (pounds) Desired/ (Min–Max)	Ground Travel Distance, (miles) Desired/ Minimum	Endurance, (days) Desired/ Minimum	Payload Dimensions, (inches)	Power Required, (watts) Average/ Peak	Platform Availability, (years) Desired/ Latest	Strawman Platform Preferred	Comments
19	Wesley Traub (Harvard)	Stratospheric Chemistry and IR Astronomy	Far-IR spectrometer	95 (90–100) K	6000 (5000–7000)	0	6/3	200 x 140 x 120	800/800	81/90	HAPP	Need long duration (>12–24 hr) at 90 K ft. "HAPP sounds potentially useful if altitude includes 90–100 K ft." Curent platforms are "adequate but could do much more science with a fixed platform." Same instrument used for IR astronomy.
20	Peter Kuhn (NOAA)	Atmospheric Remote Sensing via IR Radiometry	--	100 (70–100) K	1–5	0	2/1	--	--	81?	HAPP Mini-sniffer	"These platforms should provide the capability of some interesting new experiments. It is possible we may consider the use of the HAPP or mini-sniffer."
21	Edward Sullivan (NASA–LaRC)	Stratospheric Science	--	80–230 K	--	--	--	--	--	--	--	The proposed platforms offer no benefit over existing ones for his purposes. He desires "platforms to obtain data at many sites in the altitude range from 25 to 70 km."
22	Ronald Thomas (U. of Colorado)	UV-Spectroscopy and Minor Neutral Species in Atmosphere	Limb scanner to measure O_3 and NO_2	130 (120–170) K	500 (300–800)	0	30/10	100 x 50 x 50	25/35	84/--	HAPP	"A station-keeping platform at 130 k ft . . . would be needed to make further progress in understanding the stratosphere after the general parameters are measured."
23	J. B. Kumer (Lockheed)	Upper Atmospheric Research	High res. interferometer or spectrometer for solar absorption spectroscopy plus high res. warm optics radiometer for emission spectroscopy plus temp. sensor	70 (60–80) K	300–1600	0	365/1	72 x 24 x 24	200/1000	81/--	HAPP	"HAPP and RPV would seem to provide enhanced research capabilities . . . the HAPP provides some capabilities for long term monitoring of composition in the tropopause region."
24	W. F. Cross (Navy–ONR)	Arctic and Earth Science Programs	Various	0–5 K and 70–150 K	--	0–3000	1 to 15/0.25	--	--	80/--	--	"With probable exception of MADB all concepts could be useful . . . [Would allow] better control of in-situ and remote sensing of atmospheric and ionospheric . . . phenomena [and] relatively inexpensive medium term surveillance of oceanic and coastal phenomena."
25	Walter W. Berg (NCAR)	Atmospheric Chemistry	Measure Cl in lower stratosphere	70 (65–100) K	1400 (1000–1600)	0	7/1	60 x 60 x 12	40/100	80/84	HAPP	"The HAPP capabilities are nonexistant today and this void has resulted in major mid and high altitude trace substance sampling problems."
26	Edith Reed (for R. Hudson) (NASA–GSFC)	Atmospheric Physics	--	--	--	--	--	--	--	--	Mini-sniffer	The mini-sniffer "could be the basis of a very good research program" if used with other platforms.

TABLE 3. SUMMARY OF RESULTS FOR ASTROPHYSICS

Number	Person (Organization)	Discipline	Payload or Experiment Description	Altitude, (feet) Desired/ (Min-Max)	Payload Weight, (pounds) Desired/ (Min-Max)	Ground Travel Distance, (miles)	Endurance, (days)	Payload Dimensions, (inches)	Power Required, (watts) Average/ Peak	Platform Availability, (years) Desired/ Latest	Strawman Platform Preferred	Comments
1	Rainer Weiss (MIT)	MM and Sub-MM Astrophysics	Mm or sub-mm antenna	125 (110-130) K	600 (500-700)	0	30	60 x 36 x 24	10/100	79/--	HAPP	"... require altitudes above 100 K ft."
2	Giovanni Fazio (Harvard)	FAR-IR Astronomy	102 cm far-IR telescope	95 (93-100) K	4500	0	3	200 x 134 x 114	750/--	79/--	HAPP	HAPP would have "tremendous advantage" if it could go > 95 K ft. Even 70,000 ft is useful though.
3	J. R. Houck (Cornell)	IR Astronomy	IR telescope	65-70 K	1600 (1000 min)	0	8 hours	--	150/200	84/--	HAPP	"The HAPP would be ideal" to meet my requirements." "The HAPP would be very useful for infra-red spectroscopy."
4	T.B.H. Kuiper (JPL)	Astronomy	Sub-mm and IR telescope	High as possible	Needs further study	0	>1	--	--	--	HAPP	"A large HAPP might be able to support a light-weight radio telescope for submillimeter observations ..."
5	Michael J. Mumma (NASA-GSFC)	IR Astronomy	4 ft dish antenna or 24 in. telescope	75 (50-90) K	3000 (2000-4000)	0	30	--	100/--	82/?	HAPP	The HAPP's long endurance would make it very valuable for two payloads he now flies on balloons.
6	H. H. Aumann for self and M. Chahine (JPL)	IR Astronomy and IR Remote Sensing	1-m IR telescope	70 K	(400-2000)	0	1-7	--	--	--	HAPP	C-141 doesn't give enough altitude. "Need 70,000 ft (10,000 ft above local tropopause)." Could use new platform (didn't specify which) to "attach 1-meter diameter telescope for visibility through IR astronomy."
7	William F. Hoffmann (Steward Observatory Univ. of Arizona)	IR Astronomy	12-16 in. IR telescope	100-160 K	2000	0	1	96 x 96 x 96	60/250	--	HAPP	"HAPP has potential, but microwave power link would probably wipe out detector sensitivity (10^{-14} watt level) and vibration and irregular motions would be a problem."
[illegible]	Wesley Traub (Harvard)	Far-IR Astronomy and Stratospheric Chemistry	1-m IR telescope	95 (90-100) K	6000 (5000-7000)	0	5-7	200 x 140 x 120	800/800	81/90	HAPP	Need long duration (> 12-24 hr) at 90 K ft. "HAPP sounds potentially useful if altitude includes 90-1000 K ft." Current platforms are "adequate but we could do much more science with a fixed platform". Same instrument also used for stratospheric chemistry.
9	J. F. Ormes (NASA-GSFC)	Cosmic Ray Astrophysics	Cosmic ray detector	110 (70--) K	10,000 (5000 min)	0	400	60 x 60 x 96	300/500	79/--	HAPP	"Current balloons provide observations of 1 day. Extension of capabilities to 1 year (by HAPP) would extend energies by at least one order of magnitude."
10	Allen B. Tucker (San Jose State)	Cosmic Ray Physics	Cosmic ray scintillation spectroscope	60 (40-80) K	200 (100-400)	0	1-100	24 x 24 x 24	50/200	81/--	HAPP	Desire "sustained flight near 20 km (66,000 ft) altitude." "The high-altitude (strawman) platforms are suitable" for my needs.
11	Martin Israel (Washington U.)	Cosmic Ray Physics	--	125 K	(3500-4500)	0	1-2	--	--	--	--	Current "high-altitude balloons are very suitable" for our needs.
12	Gerald Fishman (NASA-MSFC)	Gamma-Ray Astronomy	Gamma-ray telescope	150 (115-135) K	500 (400-800)	0	5-100	50 x 50 x 30	20/30	81/86	--	None of proposed platforms is useful.
13	Lawrence Peterson (by M. Pelling) (UCSD)	X-Ray and Gamma-Ray Astronomy	X-ray or gamma-ray telescope	135 (130-140) K	1200 (1000-2000)	0	1	84 x 84 x 120	150/300	--	--	Proposed platform too low.
14	Carl Fichtel (NASA-GSFC)	Gamma-Ray Astronomy	Gamma-ray telescope	130 K	2000-2500	0	5	70 x 70 x 96	200/200	79/84	--	Our work requires altitudes of 130,000 ft.

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TABLE 4. SUMMARY OF RESULTS FOR REMOTE SENSING OF EARTH'S SURFACE

Number	Person (Organization)	Discipline	Payload or Experiment Description	Altitude, (feet) Desired/ (Min-Max)	Payload Weight, (pounds) Desired/ (Min-Max)	Ground Travel Distance, (miles) Desired/ Minimum	Endurance, (days) Desired/ Minimum	Payload Dimensions, (inches)	Power Required, (watts) Average/ Peak	Availability Date Desired/ Latest	Strawman Platform Preferred	Comments
1	S. A. Hsu L. J. Rouse for J. Bailey (Louisiana State University)	Remote Sensing for Coastal and Marine Meteorology	Various	10 (5-15) K	--	100/25	7/2	--	--	--	--	"All platforms as proposed are an improvement to meet our present capabilities." Ideally would like "constant level balloon towing at least three levels of two sensors from surface to a height of 1 km".
2	Oscar K. Huh for J. Bailey (Louisiana State University)	Marine Env. Remote Sensing	Various	15 (3-20) K	--	200	30/1	--	--	80/84	MADB HAPP Mini-blimp	The new platforms (MADB, HAPP, Mini-blimp) could yield a "100 percent improvement on experimental data base and model input information for any coastal region". Existing platforms poorly suited to our needs. Proposed platforms would be "very good".
3	Douglas Conley for Lt. Cmdr. K. Williams (Coast Guard)	Multimission Surveillance Program (Law Enforcement)	Ocean surface surveillance of vessels, ice	10 (1->20) K	500	1000/0	7/1	--	--	81/--	--	The proposed platforms would allow "wide area continuous surveillance and short term on-scene surveillance for "hot spots (drugs and/or pollution)" (HAPP for first, mini-sniffer for second?). "I feel (the proposed platforms) have potential to be of great help."
4a	J. Eckert for David McNalis (EPA)	Remote Sensing with Airborne Active Sensors	Multiwavelength LIDAR	10 (6-12) K	400 (300-500)	800/400	8 hr	48 x 48 x 48	1500/2000	79/--	--	"I do not believe the platforms would offer significant advantages over currently available aircraft."
4b	J. Eckert for David McNalis (EPA)	Remote Sensing with Airborne Active Sensors	Laser florosensor	600 (400-1500)	800 (600-800)	200/100	8 hr	60 x 48 x 48	2500/3000	79/--	--	--
4c	J. Eckert for David McNalis (EPA)	Remote Sensing with Airborne Active Sensors	Ozone monitor	3,000 (3,000-10,000)	1200 (300-1200)	200/100	8 hr	72 x 60 x 36	500/750	79/--	--	--
5	John T. Milton for R. Platt (Coast Guard)	Advanced Tech. Project Officer (Primarily Advanced Vehicles)	Vessel surveillance, radar, electro-optical and other sensors	--	--	--	--	--	--	--	--	"The proposed platforms could be useful if they are "all weather", can replace expensive manned resources, can be effective where safety considerations preclude usage of manned vehicles." These are personal not "official" opinions. "Cost-effectiveness is the key factor."
6	S. B. Levin (Geo. Wash. University)	Remote Sensing Technology Applied to Natural Resources Exploration and Environment	--	--	--	--	--	--	--	--	--	"One has to reach far for novel applications of these unmanned platforms." They would be of "not much" use in my work. Only potential benefit would be in dollar savings. Present platforms are "too expensive".
7	Timothy Gilbert (CBD Response) (EG&G Inc.)	ASW, Magnetic Anomaly Detection	Magnetic sensor plus motion sensor	1000 (0-5000)	150 (50-150)	500/100	1	3 x 3 x 48	700/700	79/--	Mini-blimp Low alt. balloon Low alt. RPV	Need a nonmagnetic motion stable platform. If any of these are nonmagnetic, would be useful.

TABLE 4. (Continued)

Number	Person (Organization)	Discipline	Payload or Experiment Description	Altitude, (feet) Desired/ (Min-Max)	Payload Weight, (pounds) Desired/ (Min-Max)	Ground Travel Distance, (miles) Desired/ Minimum	Endurance (days) Desired/ Minimum	Payload Dimensions, (inches)	Power Required, (watts) Average/ Peak	Availability Date Desired/ Latest	Strawman Platform Preferred	Comments
8	John Schoolmeester (U.S. Customs)	Provide Technology for Interdiction of Smugglers	(See Table 6)	--	--	--	--	--	--	--	--	Current platforms "could be used but (are) not considered ideal". Same applies to strawmen. They have an existing interest in two similar platforms (4000 ft, 175 lb, 4-day tethered balloon), (1000 ft, 100 lb, 8 hr, 0-35 kt mini-blimp).
9	Harold T. Rib (Federal Highway Administration)	Aerial Surveys	--	--	--	--	--	--	--	--		"Would need to make a cost-effectiveness analysis to determine value compared to existing methodologies."
10	David E. Lichy (Army Corp. of Engineers)	Coastal Engineering	Microwave and photographic and thermal sensors	3000 (1000-8000)	500 (50-1000)	10/0	14/3	24 x 36 x 36	--	82/--	Mini-blimp Tethered balloon	Comments to effect that for coastal wave monitoring would be very useful if price is less than for twice daily flights by A/C.
11	Leonard T. Crook (Consultant)	Water Resources Planning	--	--	--	--	--	--	--	--		Would be useful for remote sensing if cheaper than existing platforms.
12	Wm. H. Chapman for R. Southard (USGS)	Topographic Mapping	Aerial camera	2000 (500-3000)	40-60	Few miles	15-30 minutes	--	--	80/85	Mini-sniffer	Implicit in the comments is that the platforms must be less expensive to operate than conventional aircraft.
13	Robert M. Ragan (U. of Maryland)	Hydrology, Water and Land Resources	Aerial camera	60 K	50	--	3 hours				Mini-sniffer	There is considerable need for high-altitude photography but the current platforms such as the U-2 are too expensive for many applications. If mini-sniffer were cheap enough it would be valuable for these applications.
14	W. H. Shaw, O. Smistadt (NASA-JSC)	General Remote Sensing	--	--	--	--	--	--	--	--	--	JSC remote sensing operation is built around long-range general-purpose remote sensing aircraft. The new platform they need most is a "shirtsleeve environment, multicrew and investigator, 70,000-ft capability platform. It is in effect a lower-altitude shuttle. It must allow man/sensor interaction and the capability for the P. I. to operate and control his own systems."
15	Thomas J. Jackson (USDA)	Hydrology Research	Soil moisture monitor	500 (200-1000)	--	--	14/14	--	--	81/85	Tethered balloon	A low-altitude station-keeping platform could be used to continuously monitor soil moisture using microwave sensors. He estimates the value of the improvement over current methods is "moderate".
16	D. B. Charter (Coast Guard)	Port Safety and Law Enforcement	--	--	--	--	--	--	--	--	--	Coast Guard needs to be able to "identify and continuously monitor movement of all vessels within 200 miles of all U.S. coasts". Currently available platforms are "poor" for this purpose. Since required sensors have not yet been identified, the utility of the proposed platforms is hard to assess.

TABLE 4. (Continued)

Number	Person (Organization)	Discipline	Payload or Experiment Description	Altitude, (feet) Desired/ (Min-Max)	Payload Weight, (pounds) Desired/ (Min-Max)	Ground Travel Distance, (miles) Desired/ Minimum	Endurance, (days) Desired/ Minimum	Payload Dimensions, (inches)	Power Required, (watts) Average/ Peak	Availability Date Desired/ Latest	Strawman Platform Preferred	Comments
17	T. S. Cunningham (Coast Guard)	Marine Environmental Protection	Oil and hazardous chemical pollution monitors	1000 (800-1500)	1600-2000	300/100	1/1	75 cu ft	--	84/85	--	We "need a manned airship for our application".
18	Ted J. Czuba (Navy-Air Sys. Command)	Oceanic and Atmospheric Sensor Development	--	--	--	--	--	--	--	--	--	"None of these platforms are required in our R&D at the present time."
19	Vincent E. Noble (Navy-NRC)	Environmental Remote Sensing Technology Development	--	--	--	--	--	--	--	--	--	"Airborne platform could hover over fixed site for studying dynamics of local processes such as tide cycles, upwelling, algal blooms, and local surf conditions."

ASSESSMENT OF USER REQUIREMENTS/PLATFORM SUITABILITIES

The overall assessment portion of the study was conducted in two stages. Initially, the individual responses obtained through the survey were evaluated in terms of their specified measurement requirements and the potential capabilities of the requirements. This initial evaluation was done by user discipline categories, i.e., atmospheric sciences, astrophysics and remote sensing of the Earth's surface. As an example, all of the responses listed on Table 2 were evaluated separately, but within the context that the individual was a member of the atmospheric sciences community. A general discussion of research and measurement requirements within the atmospheric sciences discipline is provided to support the evaluations. The individual responses listed on Tables 3 and 4 are treated similarly.

The second stage of the overall assessment involved the analysis of the combined user requirements and the impact of the proposed strawman platforms on the separate user discipline categories.

User Survey Data Analysis

Atmospheric Sciences

Table 2 summarizes the replies received from the atmospheric sciences community. Research in these disciplines has been greatly stimulated during the past decade by concerns about our environment. Starting around 1969-1970, controversy about the supersonic transport (SST) and its potential effects on the ozone (O_3) content of the upper atmosphere prompted a large number of investigations to gather more data and build better models of the stratosphere*. NO and NO_2 emitted from the SST aircraft are potential destroyers of atmospheric O_3. High altitude jet aircraft also affect the environment by emitting small (submicrometer) particulates. Such particles can scatter solar radiation back into space or absorb incoming radiation. The resulting change in the Earth's overall radiation balance could affect climate and food production. Study of these particulates also leads to

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* Most of the following discussion of stratospheric research is abstracted from a paper by D.J. Hofmann which appears in The Use of Balloons for Physics and Astronomy published in 1976 by the National Academy of Sciences.

investigation of aerosols since the particles serve as condensation nuclei for aerosols. A more recent concern has been the effect on the ozone layer f the chlorofluoromethanes $CFCl_3$ and CF_2Cl_2, known by the trade names Freon-11 and Freon-12 and emitted by aerosol spray cans. This has led to a need to measure such parameters as stratospheric concentrations of Cl and ClO.

The preceding discussion provides a brief outline of a very complex set of problems. Over 100 different chemical reactions are now known to play roles pertinent to these problems. Measurements to gather baseline data and test theories are taken both in situ and by remote sensing. In situ measurements involve gathering small samples of gases and aerosols for analysis. Remote measurements are done with spectrometers and radiometers, nearly all of which use the sun as an infrared radiation source. Each type of gas molecule absorbs and radiates at particular wavelengths. Aerosol particles scatter and/or absorb radiation in specific ways depending on their size, shape and index of refraction. Thus, both absorption and emission of infrared radiation by atmospheric components are measured to determine their makeup.

All of the above discussion deals with the stratosphere, whose lowest altitude ranges from 10 to 12 km (33,000-39,000 ft) near the Earth's poles to 15-17 km (49,000-56,000 ft) near the equator. Its highest altitude is in the vicinity of 50 km (164,000 ft). The ozone layer has its peak concentration at about 25 km (82,000 ft) and so measurements at and below this altitude are particularly important for understanding man's impact on it. But a great many important environmental observations are made at much lower altitudes. Measurements at altitudes ranging from near the surface to around 5000 ft are made in studying pollution from surface sources. Emitters ranging in size from a single power plant, through a strip mine up to an entire city are studied. Measurements must be made in the immediate vicinity of the source and at points in the pollution plume ranging downwind sometimes as far as a thousand miles.

For these investigations measurements must be made on a four-dimensional grid of space and time. This calls for platforms that can remain stationary and also for mobile platforms. Since the plumes move slowly, high speed is not a prerequisite; in fact it may be a hindrance. A high speed platform may fly through the plume so quickly that spatial resolution of the measurements is poor, or it may fly out of the plume so quickly that it has difficulty reacquiring it.

It can be seen from the above discussion that the majority of investigators in the atmospheric sciences community fall into two distinct groups. One group makes measurements dealing with general chemical and physical processes in the upper atmosphere at altitudes typically above 40,000 ft. The other group investigates manmade sources of pollution and makes observations at altitudes below 5000 feet. The amount of research dealing with intermediate altitudes between 5000 and 40,000 ft is comparatively small. The entries in Table 2 have been arranged so as to emphasize this division. The first seven people listed on Table 2 all do pollution monitoring at altitudes below 5000 feet. Six of these seven people mentioned by name either the mini-blimp or tethered balloon as potentially useful in their work. The seventh, E. L. Martinez of the EPA, did not specifically mention any one platform as being of interest to him, but the platform requirements he gives for his photochemical pollution monitoring equipment seem to fit a mini-blimp very well.

The eighth person listed on Table 2, Harold N. Ballard of the U.S. Army Atmospheric Science Laboratory, requires an altitude range of 0-30,000 ft which makes him unique among the people surveyed. His overall requirements fit the Mini-Sniffer and his organization is in fact building a similar RPV to meet these needs.

The remaining eighteen people listed on the table require altitudes of 40,000 ft or more*. Of these, 6 specifically mention the HAPP as being of interest to them, 4 express interest in the Mini-Sniffer, and 3 mention the Mid-Air-Deployed Balloon (MADB).

Key parametric requirements for atmospheric science users are plotted in Figures 1, 2, and 3 as a function of altitude. Figure 1 shows altitude versus payload weight requirements. The boxes indicate acceptable ranges of altitude and payload weight for each user. Each box is numbered, corresponding to the number given each survey respondent listed on Table 2.

* Exceptions are one of M. Shumate's two experiments and one of W.F. Cross's two listed altitude ranges.

Legend:

1. Environmental Research
2. Air Pollution
3. Ambient Air Quality
4. Stack Plume Monitor
5. Pollution Monitoring
6. Tropo Air/Rain Monitoring
7. Air Quality Monitoring
8. Maneuverable In-Situ Sensor Platform
9. Atmos. Remote Sensing
10. Neutral Constituents
11. Stratospheric Aerosol Monitor
12. Stratospheric Aerosol Collector
13. Mesoscale Experiment
14. Stratospheric Aerosol Detector

16a. Tropospheric Ozone Monitor

16b. Stratospheric Molecule Radioometer

19. Far IR Spectrometer
22. UV Spectrocopy
23. Solar Absorption Spectroscopy
25. Cl Measurement

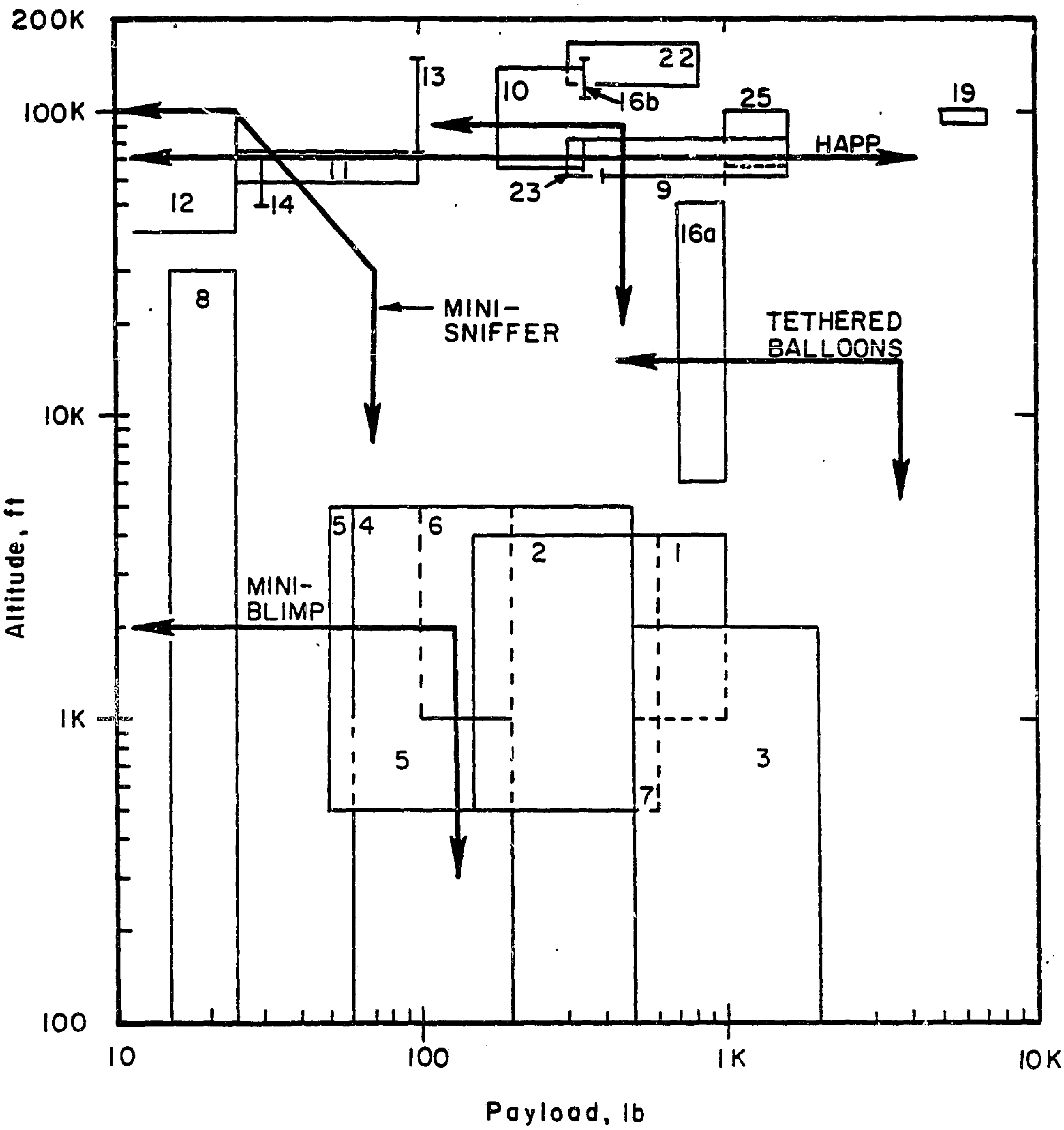

FIGURE 1. PAYLOAD WEIGHT-ALTITUDE REQUIREMENTS FOR ATMOSPHERIC RESEARCH

Legend:

1. Environ. Res.
2. Air Pollution
3. Ambient Air Qual.
4. Stack Plume Monitor
5. Pollution Monitor
6. Tropo Air/Rain Monitor
7. Air Qual. Monitor
8. Maneuverable In-Situ Sensor Plarform
9. Trace Constituents
11. Strat. Aerosols
12. Strat. Aerosols
16a. Tropos. Ozone Monitor
24. Coastal & Atmospheric Monitoring

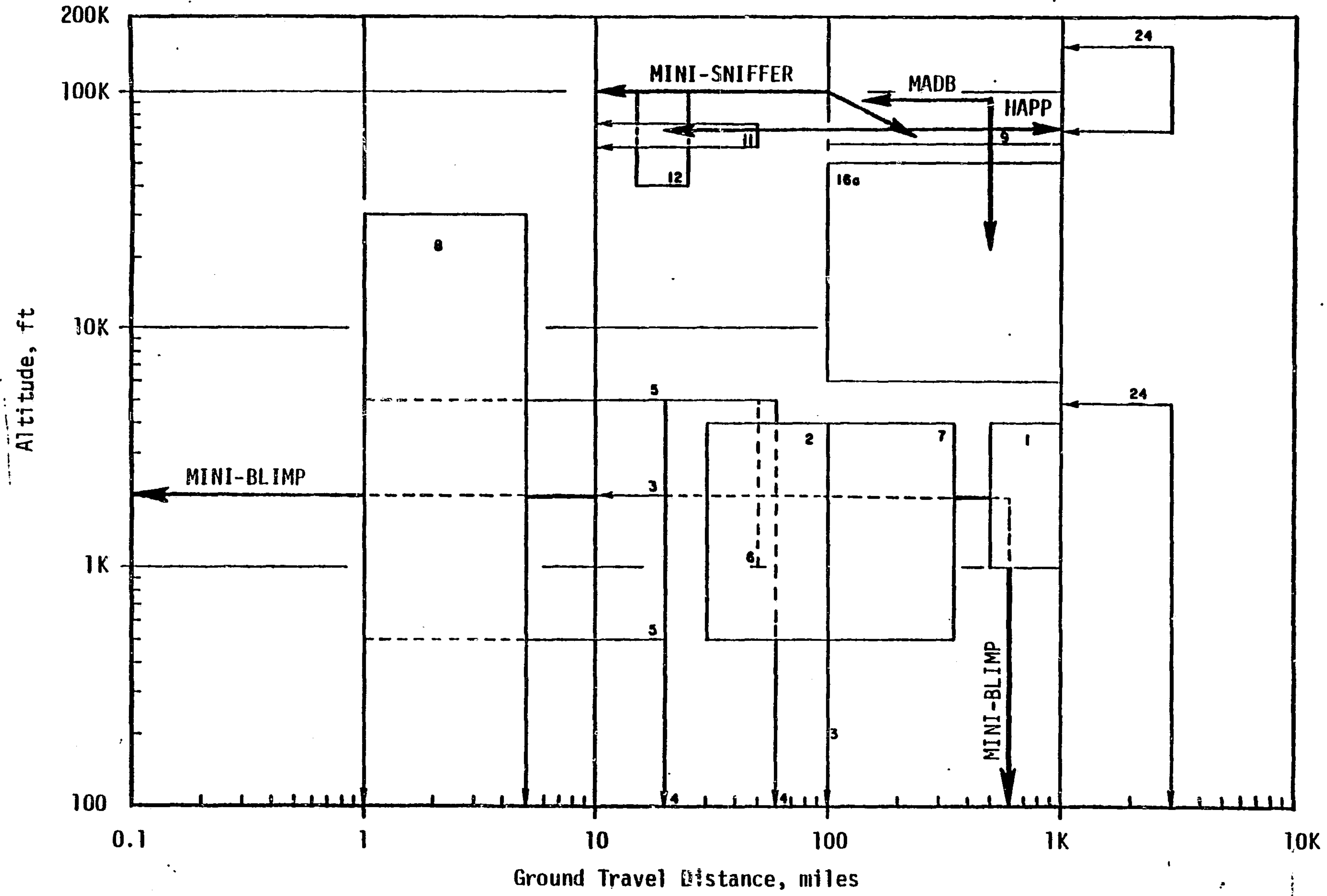

FIGURE 2 GROUND TRAVEL-ALTITUDE REQUIREMENTS FOR ATMOSPHERIC RESEARCH

Legend:

1. Environ. Res.
2. Air Pollution
3. Ambient Air Qual.
4. Stack Plume Monitor
5. Pollution Monitor
6. Tropo Air/Rain Monitor
7. Air Qual. Monitor
8. Maneuverable In-Situ Sensor Platform
9. Trace Constituents
10. Neutral Constituents
11. Strat. Aerosols
12. Strat. Aerosols
13. Mesoscale Expt.
14. Strat. Aerosols

16a. Tropos. Ozone Monitor
16b. Strat. Molecule Radiometer
19. Far IR Spectrometer
20. IR Radiometry
22. UV Spectroscopy
23. Solar Adsorption Spectroscopy
24. Coastal & Atmospheric Monitoring
25. Cℓ Measurement

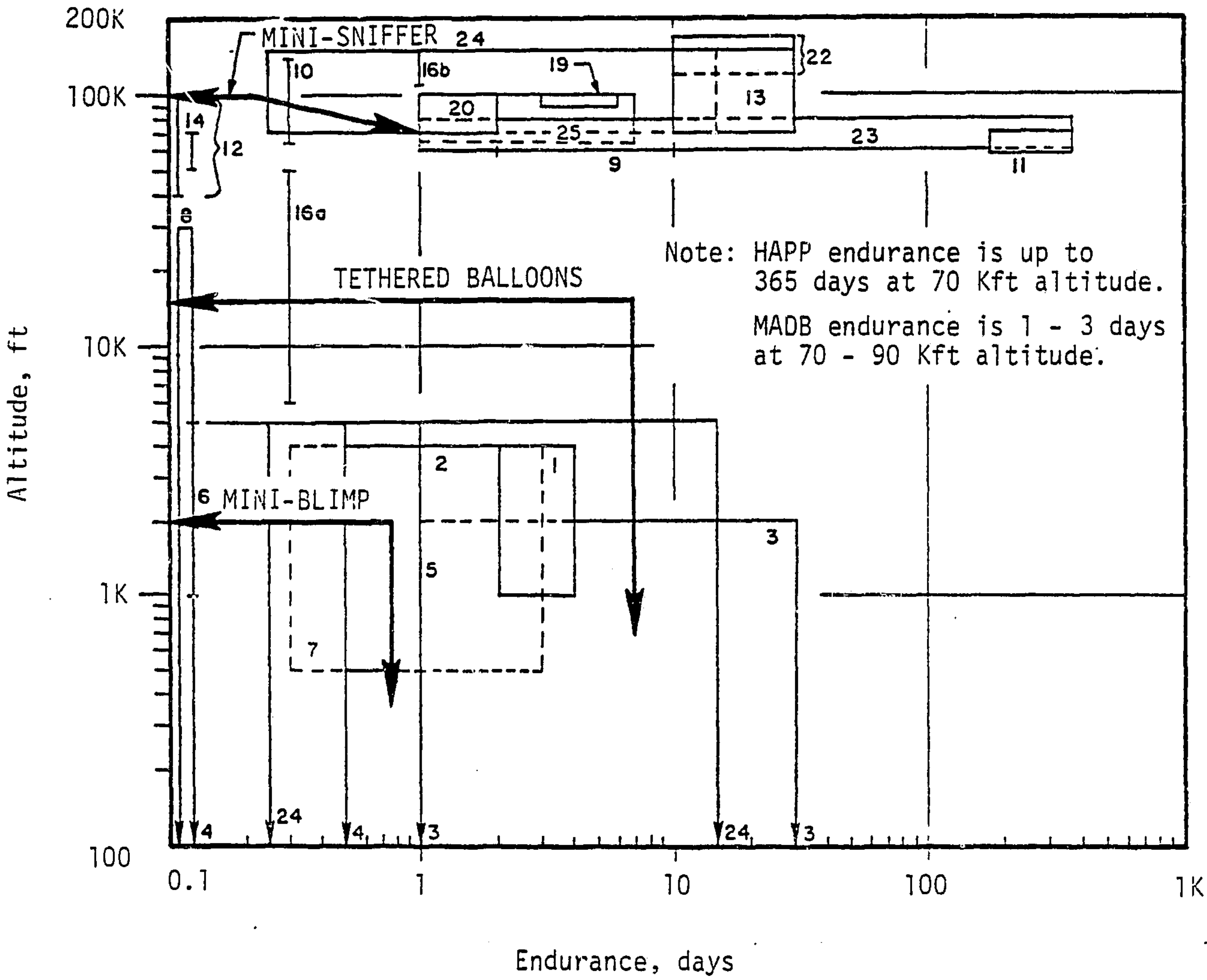

FIGURE 3. ENDURANCE-ALTITUDE REQUIREMENTS FOR ATMOSPHERIC RESEARCH

Open boxes with arrows mean the acceptable ranges extend off the graph. Dotted lines indicate the overlap of the performance boxes. Capabilities of the strawman platforms are also indicated. The clustering of low and high altitude users previously referred to can clearly be seen in this figure. It can also be seen that if the payload capacity of the mini-blimp were increased to about 500 pounds it could accommodate nearly all the low altitude applications insofar as payload weight goes. The tethered balloon payload weight capabilities are shown to be more than adequate to meet all low altitude needs. The Mini-Sniffer's payload capability is adequate for some high altitude applications, but too small for most.

Figure 2 presents ground travel range requirements as a function of altitude. It can be seen that, for most atmospheric science applications, about a hundred miles is quite satisfactory. The ground travel capabilities of the Mini-Sniffer, the mini-blimp, and the MADB would, considering those characteristics only, potentially accommodate the requirements of most of the payloads shown. Figure 3 shows endurance versus altitude. For most of the low altitude users 4 or 5 days would suffice, while a number of the high altitude investigators require longer staying times. The long endurances associated with the HAPP and the MADB, and to a lesser degree the tethered balloons, would accommodate these payloads.

Astrophysics

Table 3 summarizes the responses received from the astrophysics community. Astrophysicists use a variety of instruments that, collectively, sense radiation across nearly the whole electromagnetic spectrum as well as detecting energetic particles (cosmic rays). Astrophysical disciplines are divided by wavelength. Table 5 shows the major disciplines, their approximate wavelength bands* and the principal platforms used for making observations.

Radio astronomy for the most part requires very large, heavy antennas and the atmosphere is relatively transparent at the wavelengths of interest, so ground-based observatories are used. The millimeter and submillimeter parts of the spectrum are often regarded as part of the far-IR region and their wavelength bands are not uniformly defined by all

* The endpoints of the various bands are not rigidly defined by astronomers, and some overlap exists between bands.

TABLE 5. ASTROPHYSICAL DISCIPLINES AND THEIR PRINCIPAL PLATFORMS

Discipline	Wavelength	Principal Platforms
Radio	$10^5\mu$ and longer	Ground-based observatories
Millimeter and Submillimeter	$10^4\mu$ - 300μ	Ground, aircraft, balloons
Infrared	$10^4\mu$ - 0.7μ	Ground, aircraft, balloons
UV-Optical	0.7μ - 0.1μ	Ground observatories, a few balloons, rockets, satellites
Extreme UV	0.1μ - $10^{-4}\mu$	Rockets, satellites
X-Ray	$10^{-2}\mu$ and $10^{-6}\mu$	Balloons, rockets, satellites
Gamma Ray	$10^{-5}\mu$ and shorter	Balloons, satellites
Cosmic Ray	Energy equivalent to $10^{-10}\mu$ and shorter	Ground, balloons

astronomers, but the methods of observation are basically the same as those for the rest of the far-IR region. In the infrared band some wavelengths are absorbed to varying degrees by atmospheric water vapor, and others pass through "spectral windows" and can be observed from the ground. Infrared astronomy is done from mountain-top observatories at 7000-14,000 ft above sea level, from aircraft at 40,000-45,000 ft and from free balloons at 85,000 to 150,000 ft. Optical and some near-UV astronomy are done primarily from the ground since the atmosphere is relatively transparent at these wavelengths. However, there is distortion caused by atmospheric turbulence, and absorption increases rapidly with decreasing wavelength in the near UV; therefore, much UV and some optical astronomy is being done from satellites and, to a lesser extent, from high-altitude balloons. Radiation in part of the extreme UV band is heavily attenuated by interstellar matter, and so even satellites are of limited use for these wavelengths. For the rest of this band, satellites and some rockets are used. X-rays are virtually all absorbed high in the atmosphere. Rockets and high-altitude balloons are used at these wavelengths and, in recent years, a series of very sophisticated satellites has accounted for many important new observations. Gamma-ray astronomy requires very heavy payloads and high altitudes (125,000 ft or more), and so balloons and satellites have both been used for these wavelengths. Cosmic rays are high energy electrons and atomic nuclei of cosmic origin. As they penetrate the atmosphere they strike atmospheric nuclei and create showers of "secondaries". Much can be deduced from these secondaries, even at ground level, but the desire to directly observe cosmic ray "primaries" has motivated the use of high-altitude platforms. Because cosmic ray detectors are generally quite heavy and require long exposure times, most high-altitude experiments have used balloons.

In view of the discussion presented above, it is apparent that infrared astronomers (including millimeter and submillimeter specialists) are the best candidates as potential users of the strawman platforms since they make observations using a variety of altitudes and platform types. Cosmic ray physicists are potential users of the HAPP for some experiments because of its high endurance and high payload capability. It was also judged by those experts consulted early in the survey that there might possibly be some interest among gamma-ray astronomers. It was judged that there was little or no likelihood of interest among workers in the other disciplines.

Table 3 is arranged so that millimeter, submillimeter and infrared astronomers are grouped at the top, followed by cosmic ray physicists and, finally, gamma ray astronomers. Among the first group there is universal interest in the HAPP, although those using the longer wavelength- feel that it would need to be stationed at an altitude higher than 70,000 ft. Of the three cosmic ray specialists, two show interest in the HAPP. All of the gamma-ray astronomers consulted require very high altitudes, and so none of them could use any of the strawman platforms. Taking all the responses together, it appears that a HAPP stationed at 70,000 ft would have great potential as a platform for an infrared telescope, and such a platform could probably gain considerable support in the scientific community if further study shows it to be technically and economically feasible. The HAPP also has potential for cosmic ray studies, but the sample of cosmic ray scientists considered in this study is too small to indicate how widespread support from this community might be. These conclusions are discussed further in a later section of the report where the comments of the survey participants are reported more fully.

Figure 4 shows altitude versus payload weight requirements for the astrophysics users. It can be seen that while a HAPP at 70,000 ft would satisfy some users, higher altitudes are desired by many. None of the other platforms are applicable to astrophysics. Ground travel distance has not been plotted because it is not a critical parameter for astonomy. The only constraint on ground travel is that the platform must stay within range of whatever ground receiver is used for its telemetry system. Figure 5 plots endurance versus altitude. For most users 10 days would be adequate, while for others 30 days to a year may be required. The long endurance capability, combined with the hover characteristics of the HAPP, would accommodate all of these payloads.

At this point it is worthwhile to consider how a HAPP could best be used for astrophysical investigations. Most of the respondents in this survey are users of free balloons. In this environment, the normal mode of operation is for an investigator or small team of investigators to build an instrument, send it aloft for a short balloon flight, recover the instrument at the end of the flight and then go back to their institution to analyze the data. When a new set of measurements is to be made, the instrument (or a modified version) is reflown. This is not likely to be an efficient mode of operation for the HAPP, since it is likely to be quite difficult and expensive to launch. To be cost effective it should stay aloft for as long as possible, and so should be operated like a ground-based observatory or an observatory satellite. In these facilities, a set of general purpose instruments is typically shared by a few primary investigators and a large number of guest investigators. Astronomers wishing to use the facility submit research proposals and those that are accepted are allotted a certain amount of observing time. This system allows expensive facilities such as ground-based observatories, large satellites or HAPPs to be used in a cost-effective manner. Therefore, the fact that many of the survey respondents require 10 days or less for their observations should not be taken to indicate that a HAPP with a one-year lifetime is somehow "overkill". A HAPP operated as a

Legend:

1. MM-Wave
2. Far IR
3. IR
5. IR
6. IR
7. IR
8. Far IR
9. Cosmic Ray
10. Cosmic Rays
11. Cosmic Rays
12. Gamma-Ray
13. Gamma-Ray
14. Gamma-Ray

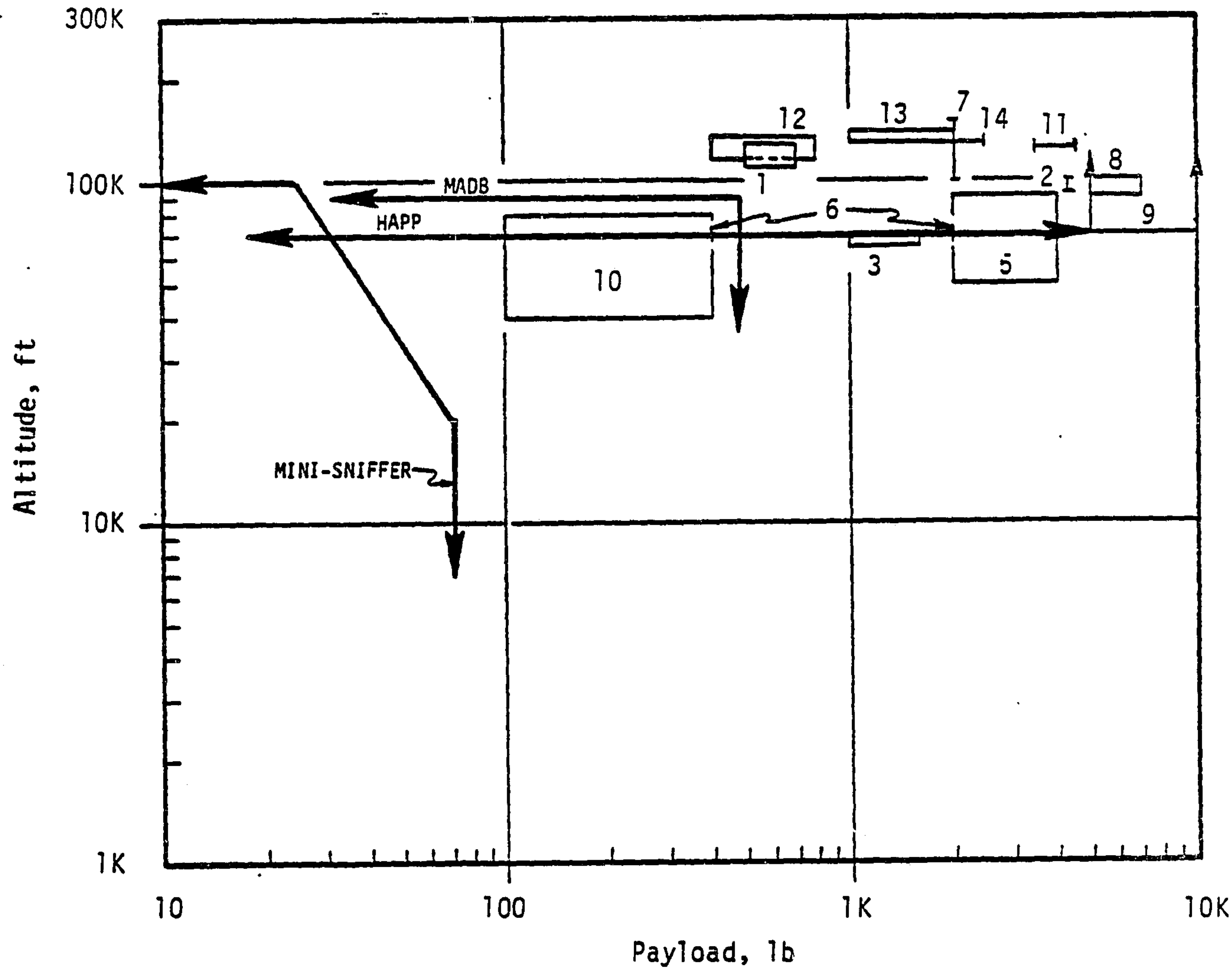

FIGURE 4. PAYLOAD WEIGHT-ALTITUDE REQUIREMENTS FOR ASTROPHYSICS.

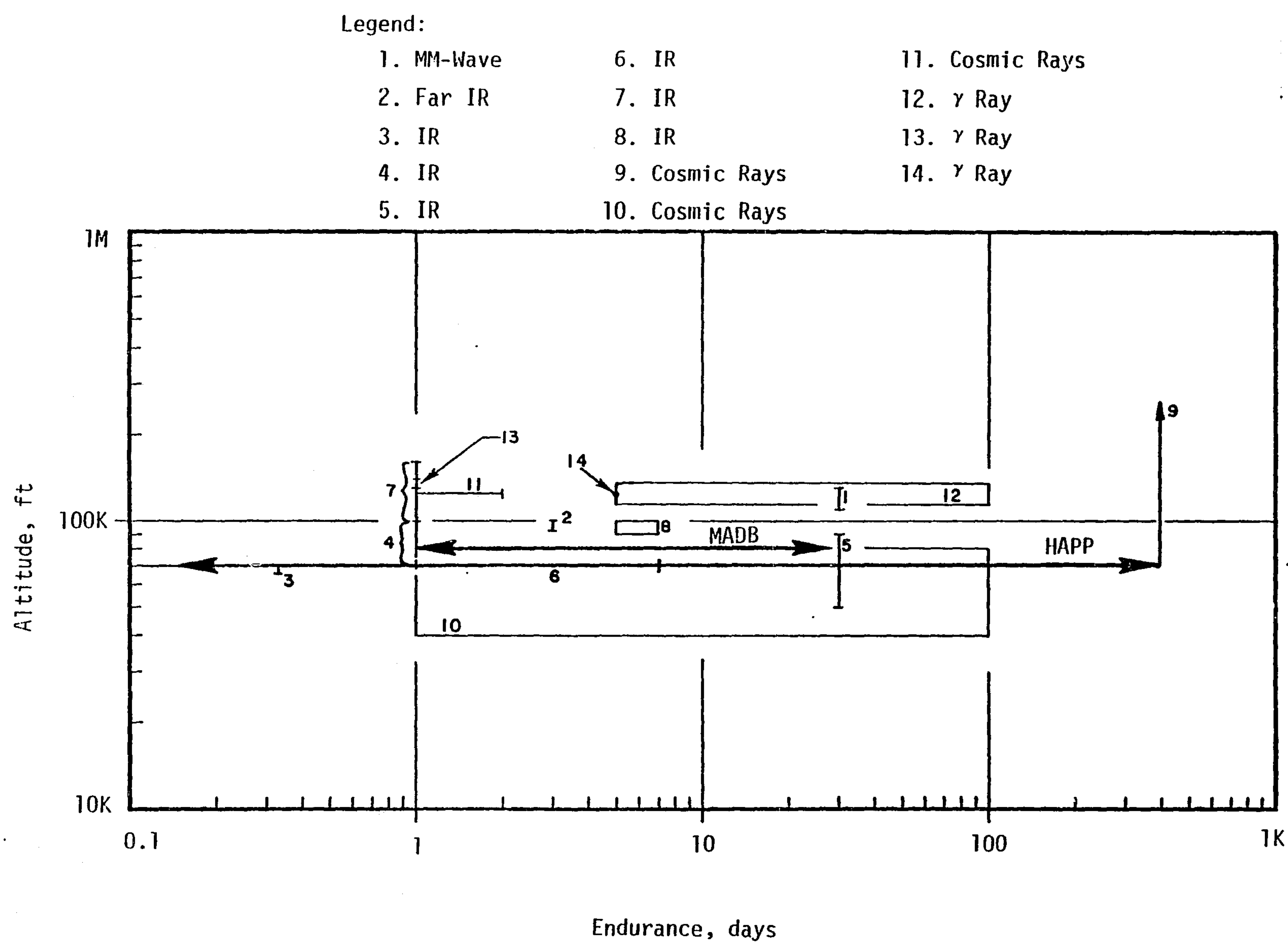

FIGURE 5. ENDURANCE-ALTITUDE REQUIREMENTS FOR ASTROPHYSICS

general purpose observatory could serve a great many scientists in a year's time. The SRI study* of HAPP cost and feasibility indicates that a large HAPP would cost about $1 million per year to operate. This is about $3000 per day, which is much less than for typical free balloon flights. So if investigations were properly organized to take full advantage of the HAPP's capability it could be cost competitive.

Remote Sensing

Table 4 summarizes the responses received from the remote sensing community. There was some interest expressed in each of the five strawman platforms but there was no consensus in favor of any particular one. This is not surprising, since for the majority of remote sensing applications, aircraft and satellites are quite satisfactory platforms. For most users a new platform can only compete with existing ones if it is less costly to use. This is reflected in the comments of many of the respondents. For applications which require very frequent coverage of a particular area (more than once per day) aircraft are quite expensive and a stationary platform such as the tethered balloon, HAPP or mini-blimp is potentially competitive. Coastal marine processes fall into this class because the interaction of tides, winds, waves and other factors creates complex temporal patterns which must be sampled at high rates if full understanding is to be achieved. Some users involved in the study of coastal processes expressed interest in the stationary platforms for this reason. Their comments are more fully discussed in later sections of this report.

Figures 6, 7 and 8 plot altitude versus payload weight, ground travel range and endurance requirements, respectively, for the remote sensing respondents.

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* Sinko, James W., High Altitude Powered Platform Cost and Feasibility Study, SRI, 1977.

Legend:

1. Ocean Surface (No Payload Weight Specified)
2. Ocean Surface (No Payload Weight Specified)
3. Vessel Surveillance
4a. LIDAR
4b. Laser Floro-Sensor
4c. Ozone Monitor
7. Magnetic & Motion Sensor
8. Smuggler Detection
10. Coastal Wave Monitoring
12. Tropographic Mapping
13. High Altitude Photography
17. Marine Pollution Monitoring

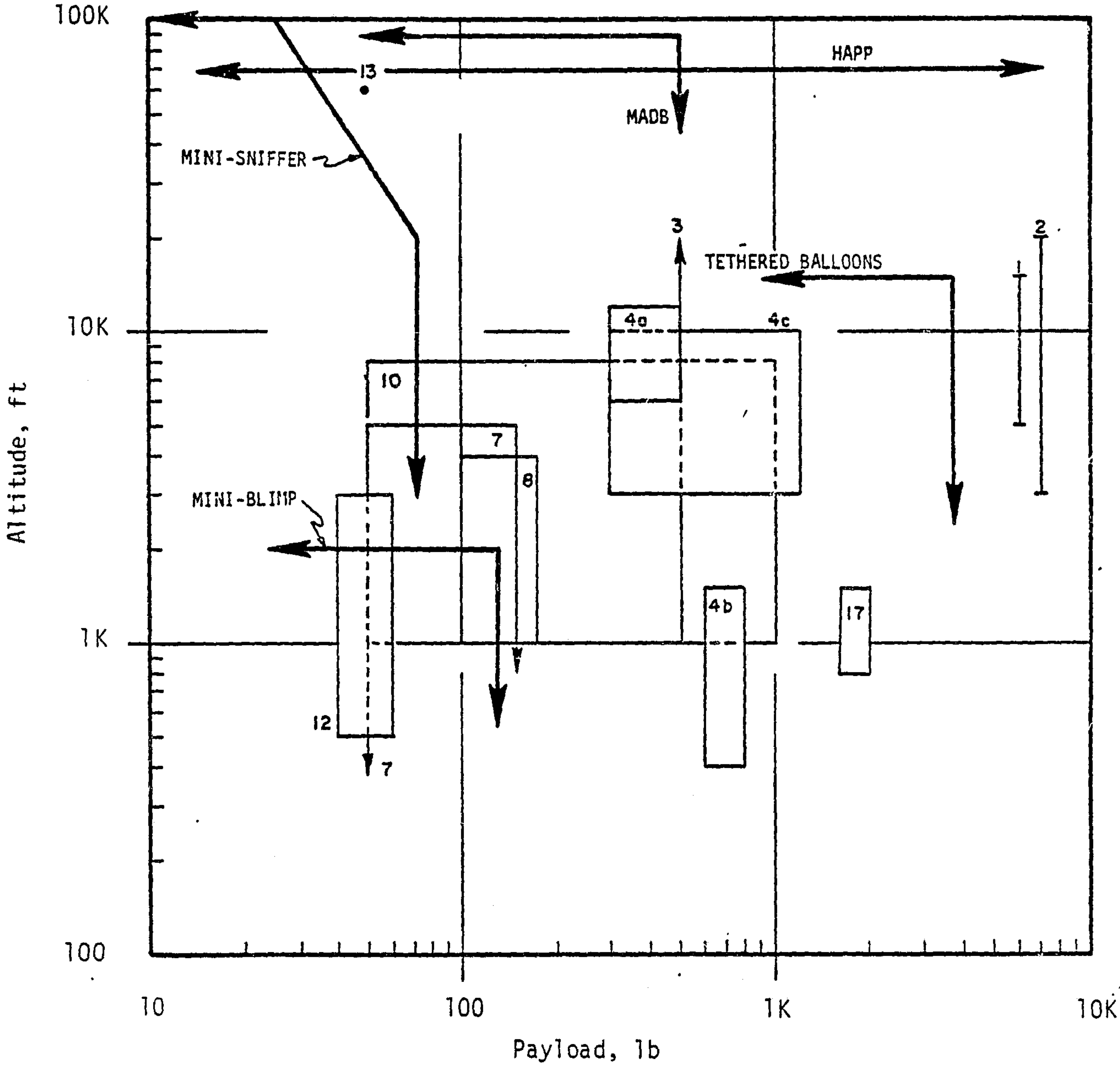

FIGURE 6. PAYLOAD WEIGHT-ALTITUDE REQUIREMENTS FOR REMOTE SENSING OF EARTH'S SURFACE

Legend:

1. Marine Meteorology
2. Marine Environ.
3. Vessel Surveillance
4a. Lidar
4b. Laser Floro-Sensor
4c. Ozone Monitor
7. ASW
10. Coastal Monitoring
12. Tropographic monitoring
17. Marine Pollution Monitor

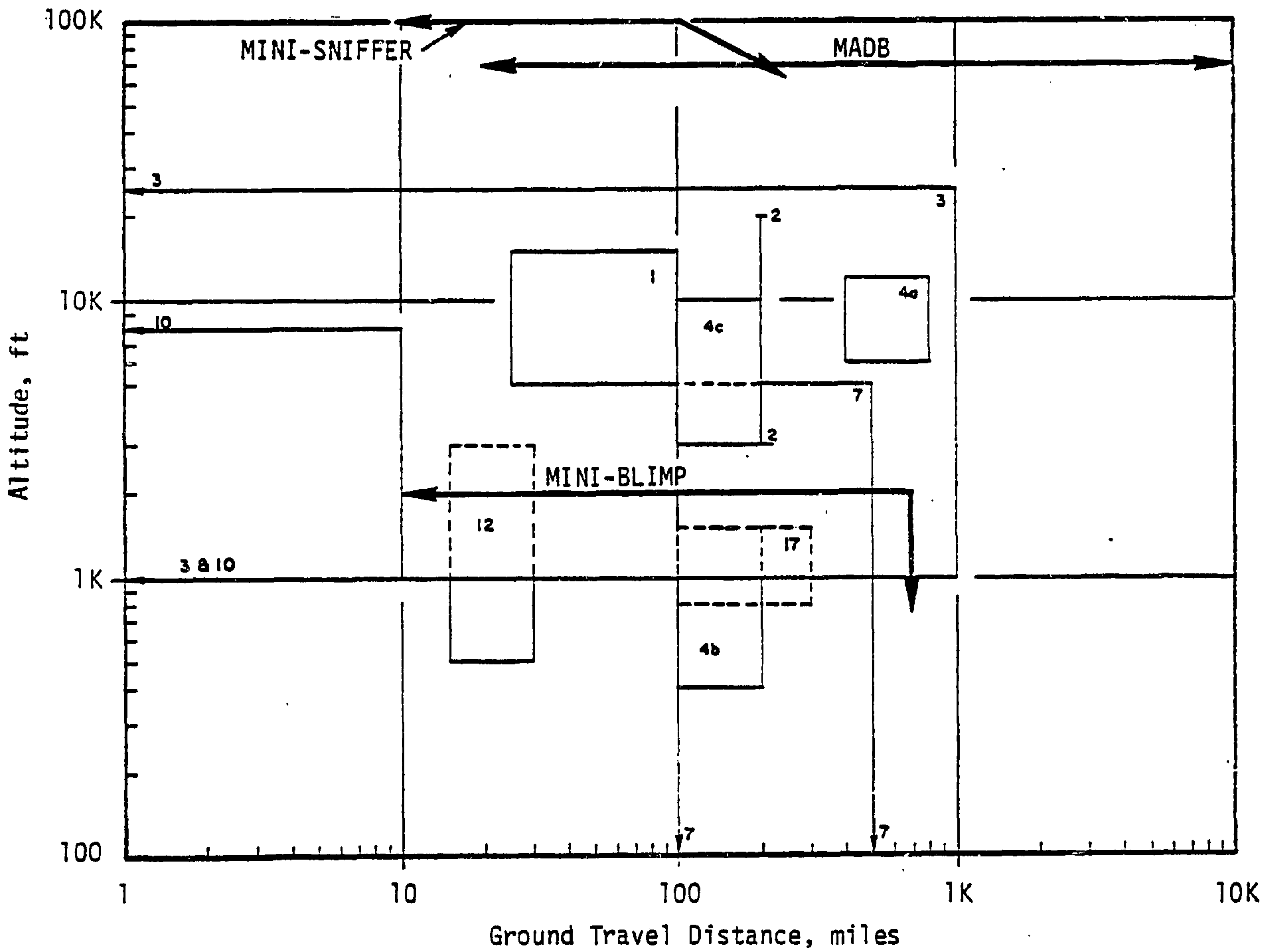

FIGURE 7. GROUND TRAVEL-ALTITUDE REQUIREMENTS FOR REMOTE SENSING OF EARTH'S SURFACE

Legend:

1. Marine Meteorology
2. Marine Environ.
3. Vessel Surveillance
4a. Lidar
4b. Laser Floro-Sensor
4c. Ozone Monitor
7. ASW
10. Coastal Monitoring
12. Tropographic Monitoring
13. High Altitude Photo.
15. Soil Moisture Monitor
17. Marine Pollution Monitor

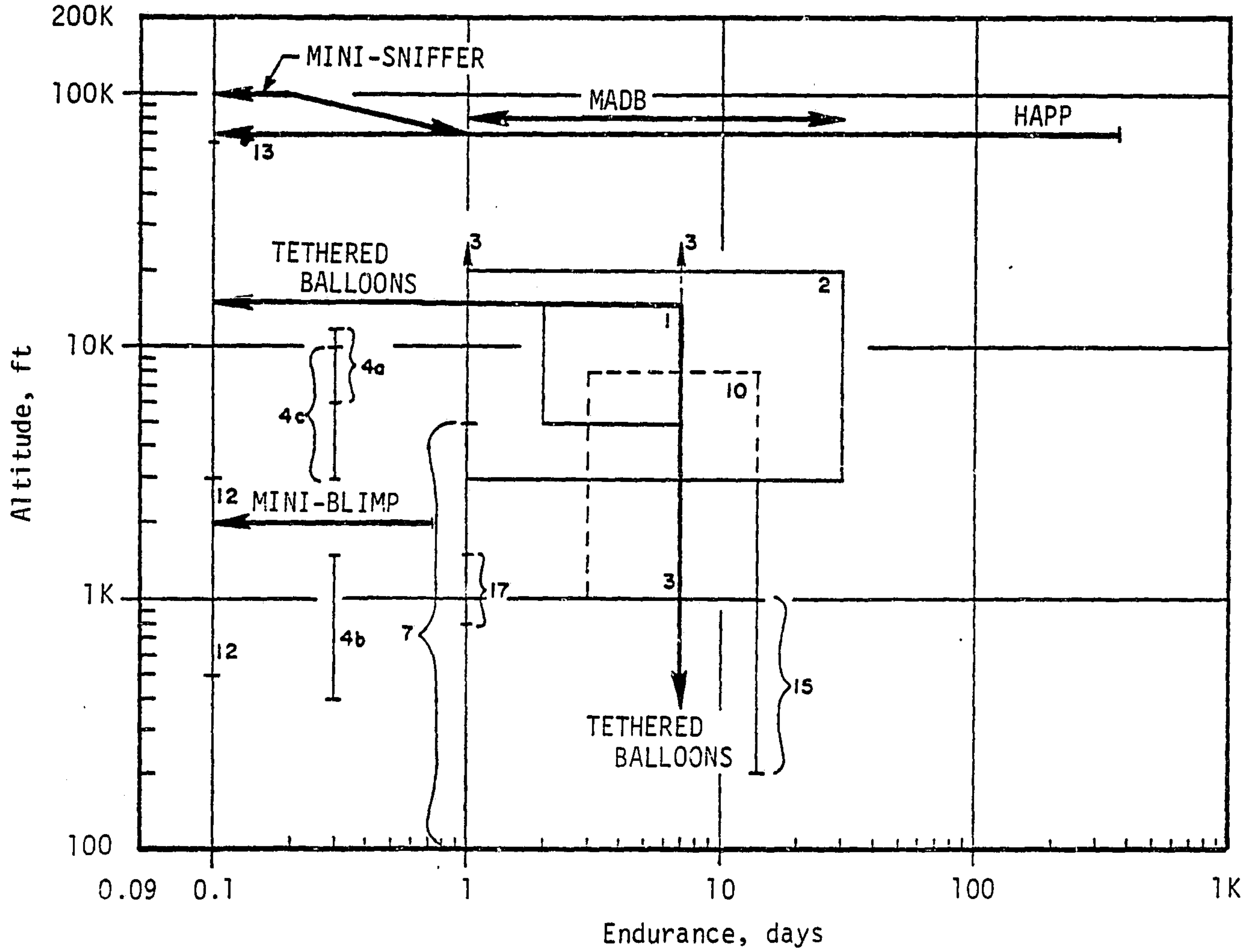

FIGURE 8. ENDURANCE-ALTITUDE REQUIREMENTS FOR REMOTE SENSING OF EARTH'S SURFACE

Evaluation of Proposed Platforms

When the answers to the questions in Part B of the questionnaire are studied and compared certain patterns emerge. By examining all the answers given by a particular respondent it is possible to gage the degree of his interest in a particular strawman platform, and by comparing the answers of all of those in a particular discipline area, it is possible to determine where a consensus of opinion exists. The conclusions which result from this kind of analysis are presented below, where sets of direct quotations are grouped under certain subject areas. We start by reporting the comments on each strawman platform, with grouping by discipline area.

High-Altitude Powered Platform (HAPP)

Of the five strawman platforms considered in the survey, the one which drew the most expression of interest was the HAPP. Its ability to carry a heavy payload and remain stationary for long periods at a very high altitude make it a unique platform which would be very useful for infrared astronomy, cosmic ray physics, and, to a lesser extent, atmospheric research.

Eight responses were received from scientists who list their discipline as millimeter-wave, submillimeter-wave or infrared astronomy. Every one of these eight people expressed at least some interest in the HAPP and several were quite enthusiastic. In reviewing their comments, start with those of W. F. Hoffmann of the Steward Observatory (University of Arizona), who was the least enthusiastic of those surveyed. Dr. Hoffman states that the HAPP "has potential" as an IR astronomy platform, but expresses concern about the possibility of the microwave power link causing interference with the IR detector and about vibration and irregular motions. He goes on to say:

> "The main workhorse for infrared balloon astronomy is likely to remain the stratospheric free balloon carrying 500 to 2000-lb experiments to 100,000-150,000 feet. The major ballooning problems are:

(1) Weather limitations on launch

(2) Damage and delay from parachute descent and truck recovery

(3) Limited range of telemetry."

Giovanni G. Fazio of the Harvard-Smithsonian Center for Astrophysics does far-infrared astronomy from free balloons. He states that for his current work none of the strawman platforms go high enough; he needs altitudes of 95,000 feet or so, but he goes on to say:

> "For infrared astronomy, altitudes $\geq$ 28 km ($\sim$95,000 ft) are most desirable to get above more of the water vapor. A platform like the HAPP would be a tremendous advantage if it could go higher. The higher weight capability ($\sim$5000 lb) would also be desirable. The 70,000-ft altitude could be used (e.g., the C-141 at 40,000 ft is now being used) but higher altitudes are more desirable. If the necessary pointing stability could be incorporated in the payload, that would also be desirable. I believe such a platform would have an advantage for infrared astronomy even during the Shuttle era."

Ranier Weiss of MIT makes balloon-borne observations in the millimeter and submillimeter regions of the spectrum. He says that the tethered balloon, MADB, Mini-Sniffer and mini-blimp are not important to his discipline but that "the HAPP, if it could be flown higher, would be". The development he desires most is "long duration ballooning with payloads greater than 500 lb and altitudes above 100K ft". He also comments that he judges that "the development of any of these systems should take second priority to the present development of the NSBF* long duration program".

Wesley A. Traub is a far-infrared astronomer and atmospheric chemist at the Harvard-Smithsonian Center for Astrophysics. He needs a "long duration (> 12-24 hours) platform at 90,000 ft". He judges current balloons to be "adequate, but they get blown out of range, so a fixed platform would be valuable because we could do much more science". He says that "HAPP's sound potentially useful, <u>if</u> altitude includes 90,000-100,000 ft and payload goes up to $\sim$5000 lb".

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* National Scientific Balloon Facility.

T.B.H. Kuiper, an astronomer at JPL, says:

"A large HAPP might be able to support a light weight (i.e., graphite epoxy) radio telescope for submillimeter wavelength observations above most of the terrestrial water vapor. The airborne observatory (NASA C-141) has a 0.91-m aperture. A telescope of 2-1/2-m aperture or greater would be a valuable improvement for submillimeter and infrared astronomy."

H. H. Aumann does infrared astronomy and infrared remote sensing at JPL. He feels that the HAPP would be a useful platform for a 1-meter-diameter telescope for visible and IR astronomy. He says the C-141 does not go high enough for many types of observations; one needs to be at least 10,000 feet above the local tropopause. The HAPP's 70,000-ft capability is thus ideal. However, he points out that all state-of-the-art experiments in IR astronomy need some cryogenic cooling, and some need a lot of it. He feels the difficulty of servicing such experiments represents a potential problem area with the HAPP*.

Michael J. Mumma of the Goddard Space Flight Center currently flies two infrared instruments--a 4-foot dish and a 24-inch telescope--on balloons. Since a major shortcoming of free balloons is that they quickly drift out of telemetry range, he feels that the HAPP would be a substantial improvement. Ideally he would like an altitude of 75,000 ft, but anything above 50,000 ft would be acceptable.

J. R. Houck, an IR astronomer at Cornell, says "the HAPP would be useful for infrared astronomy". He needs altitudes above 50,000 ft and 65,000 to 70,000-ft altitudes would be very acceptable. He feels that for his experiments "the HAPP would be ideal" and further states that "taking the NASA Learjet telescope to 70,000 ft would be a very useful ability".

Infrared astronomers are not the only ones interested in the HAPP. Two cosmic ray physicists also expressed interest. Allen B. Tucker of San Jose State University would like to be able "to monitor cosmic ray secondaries

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* While there are certainly formidable problems associated with a cryogenically cooled payload which cannot be accessed for long periods, they are not insurmountable. The Infrared Astronomy Satellite (IRAS) due for launch in 1981 will carry a cryogenically cooled telescope and has a design lifetime of one year.

at 10-25 km [33,000-82,000 ft]* altitudes at various latitudes". He says that "the current research aircraft available to me (a NASA C-141) is limited to 15 km altitude". The new capability he wants most is "sustained flight near 20 km [66,000 ft] altitude". He would like endurance of one to 100 days and a payload capacity of about 200 lb.

J. F. Ormes, a cosmic ray astrophysicist at the Goddard Spaceflight Center also finds the HAPP to be interesting provided it can carry heavy payloads. For some experiments he would require 10,000 lb, but says that even 2000 lb would be useful. He would like to be able to expose heavy payloads (>5000 lb) to cosmic rays at altitudes of 100,000 ft or more, but finds 70,000 ft to be an acceptable though less desirable altitude. He states that:

> "Observations of high energy cosmic rays require large collection area solid angle products to obtain statistically significant samples of particles. Many interesting phenomena are unobservable except at the highest energies (e.g., the source composition of rare components, the source spectra, etc.)... Current balloons provide observations of one day. Extension of capabilities to one year would extend energies by at least one order of magnitude."

He further comments that "a HAPP flight of one year for one million dollars would be very cost effective". It should be pointed out that while Battelle did not supply estimates of operating costs to the study participants, Dr. Ormes' figure corresponds exactly with the estimate made by SRI of what the HAPP would actually cost to operate.

Several people in the atmospheric science community also reacted favorably to the HAPP. A total of 19 responses were received from stratospheric chemists and physicists. Of these, six expressed interest in the HAPP. Donald Stedman, an atmospheric chemist at the University of Michigan, commented that the HAPP would be useful for long duration low stratosphere studies, and gave as an example studies of very slow photolysis rates. Ronald J. Thomas of the Laboratory for Atmospheric and Space Physics at the University of Colorado also finds the HAPP interesting; however, he would require an altitude of 130,000 ft. He says that:

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* Brackets, [ ], are words interjected by Battelle for clarity or continuity.

"Using a platform fixed over a point on the surface at 40 km (130 kft) we could monitor O_3 and NO_2 optically from 25 to 45 km over long periods. We would also monitor the solar UV penetration at the same time. The platform should contain other experiments to measure as many parameters as possible. Such platforms would be needed to make further progress in understanding the stratosphere after the general parameters are measured."

Peter M. Kuhn of NOAA is in the early stages of planning a future upper atmospheric research program using remote sensing via radiometry. He says that the HAPP and Mini-Sniffer:

"should provide the capability for some interesting new experiments. It is possible that we may consider the use of the HAPP or Mini-Sniffer at some future time for trace gas measurements. I cannot give much of a time frame since the whole program is in its infancy...I am sorry I cannot be more explicit at this time. Thank you for the [information] package since it, perhaps, may solve some problems for us."

James M. Rosen of the University of Wyoming specializes in the study of stratospheric aerosols. He would find the HAPP very useful for continuous measurements of aerosols over a one-year period. He states that, with current platforms, these experiments would be impossible. The range of acceptable altitudes is between 18 km (59,000 ft) and 22 km (72,000 ft). The payload would weigh between 25 and 100 lb.

J. B. Kumer, who does upper atmospheric research at the Lockheed Palo Alto Research Laboratory, says:

"The HAPP provides some capability for long term monitoring of composition in the tropopause region via high resolution solar absorption spectroscopy for the detection of some of the less abundant species (N_2O, CH_4 , HCl, F_{12}, F_{11}, CO) and warm optics emission spectroscopy for the major infrared active constituents (O_3, H_2O, HNO_3, CH_4, CO_2). Simultaneous seasonal and diurnal variations in composition, temperature, and transport through the altitude region of the tropopause (approximately 10 to 20 km) could be monitored on a long term basis (years perhaps) at a given point on the earth."

Walter N. Berg is an atmospheric chemist at the National Center for Atmospheric Research (NCAR). He is quite interested in the HAPP because of its ability to keep station and remain aloft for a long period. He comments that "the HAPP capabilities are non-existent today and this void has resulted in major mid- and high-altitude trace substance sampling problems (e.g., the O_3 destruction scenario has yet to be validated due to a lack of measurements)." He goes on to say, "it is highly desirable to have the ability to conduct a research experiment at 18 to 30 km [59,000-98,000 ft] altitude for extended periods to time (on the order of weeks) over a fixed location." He says that current platforms are adequate "for limited sampling....however, since only balloons and aircraft have been available, research has been tailored to these limited platforms (instead of the platform being tailored for the research). Besides inability to keep station for long periods of time, the major limitation of current platforms is cost. He explains that "present missions which I fly run about $20K per 8 hours of sample or about $2500 per hour. This should be viewed as an upper limit, especially for extended-time missions. (These figures do not include any science or research cost, simply platform costs.)" He would like to use a HAPP to "measure the total Cl content and selected gaseous and particulate Cl species in the lower stratosphere for use in a global stratosphere O_3 destruction model. The major question to be addressed is: Are anthropogenic species (i.e., CF_2Cl_2) influencing stratospheric chemistry (as, for example, with O_3)?"

For remote sensing of the Earth's surface, aircraft and satellites are, in general, quite satisfactory platforms. The 17 responses received from users in this community show clearly that with few exceptions they would only consider replacing current platforms with one or more of the strawmen if doing so would reduce operating costs.

The most notable exception to this statement is in the comments of Oscar K. Huh, who does marine environmental remote sensing at the Coastal Studies Institute of Louisiana State University. He is interested in the mid-air deployed superpressure balloon, the HAPP and the mini-blimp. He says they would allow him to "maintain IR, visual and microwave surveillance of coastal waters to determine response of wind shifts, storms and seasonal changes with repetition rate and spatial resolution totally unavailable now". This would bring about a "100% improvement of the experimental data base and model input information for any coastal region".

In summarizing the reactions of survey participants to the HAPP, it is useful to reflect on those characteristics which make it unique. It keeps station above a fixed point with no horizontal or vertical mobility, it can carry a very heavy payload and it has unusually long endurance. For remote sensing, its lack of mobility is a serious handicap except for those specialized applications where very high repetition rates are required and either the area to be observed is small, or horizon-to-horizon sensors such as radars are suitable. For atmospheric science, its lack of mobility is sometimes a handicap for experiments where in situ sensing is used, but in some sampling applications and in cases where remote sensors such as radiometers are used and required altitudes are not too high, the lack of mobility is outweighed by its long endurance potential. For astronomy, lack of mobility is not a problem and long endurance and heavy payload capacity are often important strengths. Observations of millimeter through infrared wavelengths (and some cosmic ray studies) do not always require extreme altitudes and so the HAPP appears well suited to these disciplines.

From the 17 responses received from users who do remote sensing of the Earth's surface, favorable responses to the HAPP were virtually nil. Among those who do stratospheric chemistry and physics, 6 out of 19 showed interest. Among cosmic ray physicists 2 of 3 were positive, and in the millimeter through IR astronomy group, interest was unanimous (although the degree of interest ranged from mild to considerable). It is clear that the HAPP has considerable potential as a platform for certain types of astrophysical observations. It is also evident that its potential for remote sensing of the Earth's surface is much lower than for astronomy. The situation for stratospheric chemistry and physics is less certain; however, in view of the diversity of requirements among these scientists, expression of interest by 6 out of 19 would appear to be a strong showing.

Another factor is important to consider here. To paraphrase the words of one scientist in a telephone conversation, "Look, its hard to think up applications for strange new platforms. We don't make lists of scientific problems and then go look for platforms to do the experiments. We look at the platforms and instrument technologies that are available and the scientific problems that funding organizations are interested in and then we design experiments that can use existing tools to solve fundable problems".

While it would perhaps not be true to say that every scientist operates in precisely this fashion, it certainly reflects an important reality of government sponsored research. If this fact is kept in mind while examining the responses to a survey such as this one, a natural conclusion is that, if a moderate number of scientists can find worthwhile applications for a particular platform on relatively short notice, it probably indicates that, with more time and motivation to consider the matter, many more would also find good uses for that platform.

Mini-Blimp and Tethered Balloon

The mini-blimp and tethered balloon are discussed together because most of the people who expressed interest in one of them were also interested in the other. There is a great deal of interest in these platforms among those doing air pollution and ambient air quality studies, and also some interest among those doing remote sensing of the Earth's surface. Seven responses were received from people who are involved in monitoring ambient air quality and point sources of pollution. All seven of them are interested in either the mini-blimp, the tethered balloon or both. They share a need to make in situ measurements at low altitudes, and generally find current platforms to be unsatisfactory in various ways.

Gerald Gregory does air pollution research at NASA's Langley Research Center. He finds the mini-blimp to have potential for this kind of work, saying:

> "It is desirable in many kinds of air quality experiments to locate an instrument package in an air parcel and maintain it within the particular parcel as it moves through an area. Currently one is limited to manned or unmanned balloons with no means to adjust package locations in the air parcel should meteorological conditions cause the balloon to be incorrectly located. The blimp system would have the advantage of being mobile."

He goes on to say that in his current research he needs to be able to tag and track an air parcel for 2 to 3 days and place an instrument package within it during that interval. He says that current platforms are reasonably well suited to this task "although operationally they are sometimes complex and expensive (especially manned systems)". He would find the mini-blimp to be acceptable only if it is less costly and complex than manned balloon systems and estimates that an upper limit on acceptable operating cost is "$200 per flight hour for a program of 40-50 total hours of continuous data per mission". He goes on to say:

> "Use of this type of system could be anticipated as early as 1980. However, a complex system, an expensive system, or an operationally non-flexible system would probably not be used. The use of such a system would be coordinated (in most cases) with aircraft platforms. If the blimp system becomes too complex, it could be replaced by one or more aircraft systems and a set of tetroons [constant altitude balloons] although some program (technical) trade-off would occur."

Hans W. Rudolph, of NASA's Kennedy Space Center, has responsibility for monitoring the effect of Shuttle solid rocket motors on tropospheric air and rain quality. He relates that:

> "We were gearing up to use a tethered balloon for in situ sampling of O_3 and HCl in the downwind cloud of a solid rocket launch. The tethered balloon was to launch at altitude additional tetroons with GND sondes attached to measure O_3 and HCl indirectly. The program was halted because the FAA would not authorize a tethered balloon for long periods at KSC."

He goes on to say that they are currently using a Cessna 402 from Langley to monitor the cloud from 1 to 50 km downwind for 1 to 3 hours after the launch. There are problems with this technique due to the Cessna's high speed. It frequently flies out of the cloud and then has a hard time reacquiring it. Because the cloud is difficult to see after 15-20 minutes, he feels that remotely piloted vehicles would not be practical for following it. He feels that a manned blimp or perhaps a helicopter would be the best solution to his particular problem; he further states that "these systmes should have considerable use in air quality sampling, both R&D and eventually for routine monitoring".

James A. Armstrong of the Denver Research Institute currently uses air samplers carried aloft by tethered balloons to monitor airborne particulate and gaseous pollutants from plumes of point and non-point source emitters such as power plants and strip mines. He says:

> "Monitoring of source emissions using aircraft is not feasible at low flying altitudes and in close proximity to a source because of the poor time and spatial resolution, due to the necessary speed of aircraft and for safety reasons. Tethered balloons do not have the horizontal mobility desired... The mini-blimp appears to be quite suitable [for this application. It would] allow real time in situ particle and gas sampling to be conducted at locations and with mobility not possible using current airborne sampling techniques which include aircraft and tethered balloons."

Charles K. Fitzsimmons is with the EPA and does ambient air quality monitoring. He finds both the mini-blimp and tethered balloon concepts to be potentially useful in his work. He needs to sample air in urban areas at altitudes from near ground level to about 2000 feet. He says that "fixed wing aircraft are restricted to 1000 feet [minimum altitude], and helicopters to 500 feet away from buildings or structures occupied by people. They also cause noise problems for urban areas". He also comments that operating cost is a problem with aircraft. Costs for a mini-blimp or tethered balloon system should be less than for aircraft--about $200 per flight hour. He would like to have a "tethered balloon which could carry about 1000 lb of sampling equipment and be powered from the ground. [The] platform could provide many vertical soundings during a given day's sampling period". He says such balloons could be considered as vertical extensions of fixed monitoring sites and "several systems could be deployed simultaneously from several locations within a given study area. They would provide continuous data 24 hours per day for a few days at a time".

E. L. Martinez is also with the EPA and does air pollution field studies. He would like to fly a 300-lb payload at altitudes from 500 to 4000 ft with a range of 30 to 100 miles to make in situ measurements "to obtain horizontal and vertical profiles of photochemical pollutant (ozone, NO_x, HC) concentrations upwind, over and downwind of an urban area".

While Mr. Martinez does not specifically mention the mini-blimp in his comments, it appears that a mini-blimp somewhat larger than the strawman mini-blimp would be suitable for such missions. He finds that aircraft are "generally good [for his applications] but very costly and not very flexible as to locations of measurement and times of day or duration of flights". He says that the strawman platforms "appear more flexible and some perhaps less costly [than aircraft]".

Donald Stedman is an atmospheric chemist at the University of Michigan. He believes that the mini-blimp would be valuable for "low altitude power plant plume studies, especially at night...or in mountainous terrain". He specifies a desirable range of altitudes from ground level to 5000 ft, with a 3000-ft ceiling being acceptable. He notes that this means altitude above ground level and could translate into 9000 ft above mean sea level. Desired range would be 60 miles with 3 to 13 hours endurance and a 60 to 200-lb payload. He further comments, "I believe the mini-blimp could well be an entity with which NASA Wallops could provide an entirely new dimension in in situ plume measurements".

Bernard Zak of Sandia Laboratories is developing an automated air pollution monitoring payload for the DOE's Office of Health and Environmental Research. This payload is designed to be launched into plumes from sources ranging in sizes from power plants to entire cities. He would like to have a platform which would allow the payload to move with the plume for periods ranging from hours to days and travel up to 1000 miles downwind from the source. For developmental versions of this payload, manned balloons have been used. In future, a tethered balloon and winch could be used to take vertical profiles. For applications requiring a mobile platform, a helicopter has been considered. The payload would be suspended 100 to 150 ft below the helicopter to minimize effects caused by the rotor downwash. A platform such as the mini-blimp would be extremely useful for his applications because it is mobile, yet can fly quite slowly with minimum disturbance to the air. However, he desires a payload capacity of 1000 lb (minimum acceptable: 500 lb) and a range of 1000 miles (minimum acceptable: 500 miles). He also requires that the operating cost be comparable to that for small aircraft (about $100/hr). He comments that if he could find a vendor who would supply a mini-blimp with these characteristics he would "sign the purchase order tomorrow".

Interest in the mini-blimp and tethered balloon was also expressed by some people who do remote sensing of the Earth's surface. One of the most notable comments came from John Schoolmeester, who is Chief of the Engineering Services Branch of the U.S. Customs Service. He has informed Battelle that the Customs Service is seriously considering development of its own versions of the tethered balloon (tethered aerostat) and the mini-blimp (RPV powered aerostat) for interdiction of smugglers. The characteristics of the platforms under consideration are shown in Table 6.

David Lichy is at the Coastal Engineering Research Center of the Army Corps of Engineers. He desires a platform which could operate at about 3000 ft altitude continuously (or nearly so) for 3 to 14 days and carry a payload of about 500 lb. The purpose is to measure wave direction, height and length with microwave or photographic sensors and current interactions by means of a thermal scanner. High repetition rates are required. He explains that:

> "When designing coastal structures or harbors, it is important to understand the interaction of the ocean waves with the current, bottom topography and local shape. In the past aerial photography, side-looking airborne radar and thermal scanners have provided interesting data. Unfortunately this data is limited by one shot deals. If these platforms/systems can provide repetitive coverage hourly for one to two weeks at a cost less than sending up planes twice daily they might be feasible. If not, the cost could not be justified by us. The reason for one to two weeks is to ensure a variety of wave conditions to study."

Vincent E. Noble, of the Naval Research Laboratory, is involved in environmental remote sensor technology development. He finds the tethered balloon and the mini-blimp of interest because of their ability to hover. (The HAPP also hovers but he comments that "it appears to be speculative".) He would use these platforms for:

> "proof-of-concept experiments with new sensors, and for studying fixed-site dynamic processes. The airborne platform could hover over a ship in the case of sensor experiments involving an extended-mode test cycle requiring continuous (oceanographic) surface truth. The airborne platform could hover over a fixed site for studying

TABLE 6. CHARACTERISTICS OF PLATFORMS UNDER STUDY BY U.S. CUSTOMS SERVICE FOR INTERDICTION OF SMUGGLERS

Platform #1 — **Tethered Aerostat**

Altitude - 4,000 ft. max.

Endurance - 4 days max.

Payload - 175 lbs.

Sensor (one at a time)

A. Radar - detection of small craft and light aircraft

B. IR - detection of small craft and light aircraft

C. Beeper D.F. receiver - detection of tagged suspect aircraft and boats

Considerations - Power Source, direction indication sensor link

Platform #2 — **RPV Powered Aerostat**

Altitude - 1000 ft. max.

Endurance - 8 hours

Payload - 100 lbs. (excluding fuel)

Speed - 0 - 35 kts.

Sensor - (one at a time)

A. Low light level TV - detection of personnel vehicles and small craft

B. Mini IR - detection of personnel vehicles and small craft

Considerations: data link for control, sensor relay, direction indication, Power Source the dynamics of local processes such as tide cycles, upwellings, algal blooms, and local surf conditions."

Three people at the Coastal Studies Institute of Louisiana State University also expressed interest in these types of platforms. Oscar K. Huh specified the HAPP, the mini-blimp and the mid-air deployed balloon as being of interest to him. He says these platforms would be useful to "maintain IR, visual and microwave surveillance of coastal waters to determine [their] response to wind shifts, storms and seasonal changes with repetition rate and spatial resolution totally unavailable now. [They would provide] a 100% improvement of experimental data base and model input information for any coastal region". S. A. Hsu and L. U. Rouse, also of the Coastal Studies Institute, did not specify interest in a particular platform but said that all the strawmen "as proposed are an improvement to meet our present capability [for determining] the spatial and temporal variability of the height and thickness of the top of the marine surface boundary layer, which relates to electro-optical meteorology and cannot effectively be done by conventional methods".

Taking the comments of these three workers together with those of Mr. Lichy of the Army Coastal Engineering Research Center, and Dr. Noble of the Naval Research Laboratory, it can be concluded that the platforms which can keep station (HAPP, tethered balloon, mini-blimp) have potential use for study of marine processes because of a requirement for making measurements at high repetition rates for extended periods of time.

Mini-Sniffer

The Mini-Sniffer received expressions of interest from the atmospheric science community and also from two people who do remote sensing of the Earth's surface. Donald Stedman, an atmospheric chemist at the University of Michigan, commented that the "RPV would be very good for vertical profiling of chemicals". James M. Rosen is a specialist in stratospheric aerosols at the University of Wyoming. He says that the "Mid-Air Deployed Balloon, the HAPP and the Mini-Sniffer are relevant systems to our present research. The Mini-Sniffer is probably most suitable to our present research needs. At present we use balloons in our stratospheric research. These platforms do not offer horizontal mobility that is sometimes required in certain sampling programs. A platform such as the Mini-Sniffer would be useful to us in conducting routine aerosol soundings to 100,000 feet".

Neil H. Farlow is at NASA's Ames Research Center and does aerosol collection and analysis in the stratosphere. He says that current platforms are satisfactory for his purposes "except for geographic restrictions. Only certain locations are available for aircraft and balloon deployments." He would like "the ability to collect samples at different geographic locations around weather systems and volcanic eruptions. The mini-sniffer...would provide added capability over currently available equipment. This aircraft would allow more frequent flights and provide more diverse geographical deployment capability." He describes an experiment for stratospheric aerosol collection which requires that a payload weighing 3 to 25 lb and measuring 4 x 4 x 4 inches be carried to altitudes ranging from 40,000 to 100,000 ft. Only a few minutes are required for actual collection of the sample.

Harold N. Ballard, of the U.S. Army Atmospheric Sciences Laboratory (ASL) at White Sands Missile Range (WSMR) relates to Battelle that:

> "ASL is presently developing, in association with the Applied Physics Laboratory of Johns Hopkins University, an RPV. Its initial purpose is to gather atmospheric data (meteorological, composition, electric fields) to characterize the atmosphere over the High Energy Laser Test Facility (HELTF) at WSMR, New Mexico. The RPV serves as a platform for approximately 20 sensors [for use] in the altitude interval surface to 27 thousand feet over HELTF. It serves as a relatively low-cost maneuverable atmospheric probe."

The RPV will have a ceiling of 30,000 ft, endurance of 2-3 hours and carry a 25-lb payload. He goes on to emphasize that the primary motivation for development of the RPV is excessive cost of manned aircraft.

Edith Reed is an atmospheric physicist who works with balloon-borne payloads at NASA's Goddard Space Flight Center. She finds the Mini-Sniffer to be a very interesting platform despite the fact that its 25-lb payload is, by the usual standards of stratospheric research, quite small (1000 lb is more typical). She feels that it could probably carry one of the following: a temperature sensor; a water vapor sensor; an O_3 sensor; and NO sensor. Combining an ability to carry such sensors with a sufficiently accurate navigation capability would make for some very interesting scientific possibilities. One example would be to look at the thunderstorm injection problem by flying NO and water vapor sensors above a tropical thunderstorm. Another example, where the Mini-Sniffer could be "the heart of a very good research program" would be to look at the problem of troposphere-stratosphere interchange near the jetstream. This is a difficult problem requiring coordinated measurements at several altitudes. By using the Convair 990, the WB-57, the U-2 and the Mini-Sniffer, each at its own appropriate altitude, one could carry out research not now practical.

Two people who do remote sensing of the Earth's surface also expressed interest in the Mini-Sniffer. Robert M. Ragan does research on hydrology and water and land resources at the University of Maryland. He believes that there is a need for a "national program of U-2 type [aerial photography] coverage on a cycle of 3 to 5 years". He feels that the Mini-Sniffer might help meet this need. He comments that high-altitude aerial photography is currently available using NASA U-2s and private executive jets but "cost and availability of aircraft and personnel is very limiting. For regional coverage...at a time designated by the user, U-2 type imagery in an enlarged 1:24000 format should cost no more than $250 per frame including the flight and processing".

William H. Chapman is with the U.S. Geological Survey and uses aerial photography for production of maps. He would like a platform which would "provide survey parties working on mapping projects with an unmanned, low-altitude aerial imaging capability." He comments that tethered balloons were tested for this application and found unacceptable. He says that "an automatic film camera or video camera would record the images. This system is to obtain up-to-date imagery in areas of changes for augmenting the older mapping photography and to image ground control points, temporarily marked by cloth panels, for transfer to the mapping photography. The aircraft or balloon must be small and light enough to be transported by a light truck and preparation time for launch must be less than five minutes. This system will improve the accuracy and reliability of the maps and probably would lower costs." He believes that an RPV which could carry 40 to 60 lb to a 2000-ft altitude for 15 to 30 minutes would be suitable for this mission.

Mid-Air Deployed Balloon (MADB)

The platform which received the fewest expressions of interest was the Mid-Air Deployed Balloon (MADB). Part of the reason for the lack of interest is probably a perception that this platform is likely to be quite expensive to launch. One person commented that it will cost at least as much as a balloon launch and aircraft mission combined. With one exception*, all those expressing interest in the MADB are involved in stratospheric research. For example, James M. Rosen of the University of Wyoming specializes in the study of stratospheric aerosols. He commented that the MADB is "relevant to our research" but did not describe any specific application. He found the HAPP and Mini-Sniffer to be more interesting. Neil H. Farlow of NASA's Ames Research Center is another stratospheric aerosol researcher. He did not make a specific reference to the MADB, but he did make it clear that, for his applications, a major shortcoming of current platforms is that only certain locations are available for balloon deployment. By implication, a MADB might solve some of his problems.

* Oscar K. Huh does remote sensing of the ocean's surface. He mentioned the MADB as one of three platforms of interest to him. His comments are discussed in the section on the mini-blimp and tethered balloons.

Arthur Schmeltekopf is the head of the stratospheric sampling group at NOAA's Boulder, Colorado laboratories. He comments that the new capability they need most is an ability to safely launch and track balloons from remote locations. He says the MADB "would help, but it will be much more expensive" than normal balloons. Acceptable costs would lie in the range of $2000-$5000 per launch. D. J. Hofmann of the University of Wyoming specilizes in stratospheric aerosols, ozone and atmospheric electricity. He comments that a MADB for light payloads (25 lb) "would be useful".

In summary, there were few favorable comments on the MADB and none could be classified as enthusiastic.

New Capabilities

Mission Alternatives Desired

One of the questions included in the survey was: "What new methods or mission alternatives do you desire?" A few respondents interpreted this to mean "Which of the strawmen do you prefer?" but most read it the way it was intended; i.e., "Of all possible new capabilities, which do you need most?" Compiling a list of the answers given to this question by those who correctly interpreted it makes it possible to gage how close the strawman platforms come to meeting the immediate needs of workers in the various discipline areas. This list is given below. The last name of the respondent is given first and his answer follows. Answers from the remote sensing community are given first.

Hsu/Rouse — "Ground launched constant level balloons at several altitudes from say, 500 ft to 10,000 ft from coast to offshore and vice versa from ship to shore."

Conley — "Better and new ways to perform surveillance."

Eckert — "We proposed several years ago to support a large aircraft as a test bed for remote sensing equipment developed by both EPA and other agencies. We could not fund it. It is still a good idea."

Levin — "Low cost remote sensing platforms having altitude-stabilization like that with which some A/B radar is equipped. For altitudes 10-30 K ft."

Gilbert	"1. Non-magnetic platform. 2. Motion stable platform or a motion recordable platform."
Schoolmeester	He relates to Battelle that the U.S. Customs is considering development of mini-blimp and tethered balloon for surveillance. These are his highest priority needs.
Crook	"Multi-spectral scanner oriented toward water resources..."
Chapman	He needs an inexpensive, flexible, low-altitude platform for aerial photography to aid survey parties. Tethered balloons have been tried without success. He feels the Mini-Sniffer has potential.
Ragan	"A national program of U-2 type coverage on a cycle of 3-5 years."
Charter	"Ability to identify and continuously monitor movement of all vessels (including fishing vessels) within 200 miles of all U.S. coasts."
Shaw/Smistadt	They want an aircraft capable of carrying large payloads and investigators at 70,000-ft altitudes.

There is a wide variety of needs expressed here with no consensus in support of any of the strawmen. Answers from the astrophysics community are reported next.

Mumma	"Long duration (30 days) heavy balloon payloads to $\sim$30 km."
Weiss	"Long duration ballooning with payloads greater than 5000 lb and altitudes above 100 K ft."
Fazio	Want "higher altitudes".
Aumann	"C-141 not enough altitude... need 70,000 ft."
Fishman	"High altitude (> 120,000 ft), long duration (10-100 days)."
Ormes	"Capability to expose heavy payloads (> 5000 lb) at altitudes $\geq$ 100,000 ft for periods of months to years."
Tucker	"Sustained flight near 20 km altitude."
Traub	"Longer duration (> 12-24 hours) at 90,000 ft."

It appears from these answers that while the astrophysics community shows strong interest in the HAPP, it does not meet the immediate, high priority needs of most of these scientists. Their most acutely felt need is for free balloons with higher altitudes, longer endurance and heavier payloads. However, this is undoubtedly due in large part to the fact that nearly all of the astrophysicists surveyed are current users of free balloons and are used to thinking in terms of the advantages of improvements in this basic platform technology. The HAPP is a very novel concept and most, if not all, of these investigators were first exposed to it by this survey. Their broadly favorable response to it indicates that despite the fact that it may not meet their immediate needs, they could devise many new experiments if the HAPP were available to them. This would be especially true if the HAPP could operate at higher altitudes than the strawman. A HAPP at 100,000 feet would have wide appeal and a 130,000 feet HAPP would be valuable to a very broad group of astronamers.

Next we list the answers of those who specialize in high-altitude atmospheric measurements.

<u>Farlow</u> "The ability to collect samples at different geographic locations around weather systems and volcanic eruptions."

<u>Hofmann</u> "Measurements to very high altitudes (50 km)."

<u>Schmeltekopf</u> "Good safe balloon launching techniques from remote locations."

<u>Krimigis</u> "The altitude range of greatest interest in upper atmosphere physics is ~25 km to ~150 km, i.e., above typical balloon altitudes and below typical satellite orbits."

<u>Farmer</u> "The ability to sample altitudes (say 5 km intervals) from surface to tropopause, at all latitudes (including and particularly polar regions) is important. This is expensive, and in some locations impossible with conventional aircraft... For upper atmosphere studies, the outstanding advancement needed is the ability to take relatively large payloads to ~100 km.

<u>Sullivan</u> "Platforms to obtain data at many sites in the altitude range from 25 to 70 km. Currently balloons and rockets can be flown from a very restricted number of sites with poor geographical coverage."

<u>Thomas</u> "We desire higher altitudes (~40 km)."

<u>Kumer</u> "Those described under categories HAPP and RPV would seem to provide enhanced research capabilities."

<u>Cross</u> "1. Launch/recovery in winds up to 30 knots
2. Station keeping and precise altitude control."

<u>Berg</u> "It is highly desirable to have the ability to conduct a research experiment at 18 to 30 km altitudes for extended periods of time (on the order of weeks) over a fixed location."

There are a variety of needs expressed here, but if there is a consensus, it is that higher altitudes are the most immediate need of this group. However, the same comments apply here as to the astrophysicists. Many of these people are current balloon users and they have never before had an opportunity to consider potential uses of platforms such as the HAPP or Mini-Sniffer. The positive responses to the HAPP and Mini-Sniffer given by some respondents in other sections of the questionnaire indicate that, while these platforms may not serve immediate needs, they would be very useful to some investigators if they were available.

Lastly we list the answers of those who do low-altitude atmospheric sampling.

<u>Zak</u> — In a telephone conversation he related that he has an immediate need for a platform such as the mini-blimp provided it could carry 500-1000 lb for at least 500 miles.

<u>Martinez</u> — "(1) Capability to follow pollution plume 100's of miles.
(2) Capability to obtain parameter profiles to 5-15,000 ft at repeated intervals and at given fixed points.
(3) Capability for horizontal flights criss-crossing a city."

<u>Fitzsimmons</u> — "Use of tethered balloon which could carry ~1000 pounds of sampling equipment and be powered from the ground. Platform could provide many vertical soundings during a given day's sampling period."

<u>Armstrong</u> — "The ability of <u>real time</u> in situ plume sampling of pollutants at various locations downwind from an emitting source including both close in and reasonably far distances."

<u>Rudolph</u> — His immediate needs would be well served by a tethered balloon except that the FAA will not permit him to fly it.

<u>Stedman</u> — "Mini-blimp - Low altitude power plant plume studies, especially at night.
HAPP - Studies of very slow photolysis rates...
I believe the mini-blimp could be an entity with which NASA Wallops could provide an entirely new dimension in in-situ plume measurements."

<u>Gregory</u> — "Our current needs are better methods to:
1. Tag and track an air parcel for 2-3 days.
2. Place an instrument package in the said air parcel."

<u>Ballard</u> — "RPV and perhaps tethered balloons. Low altitude tethered balloons would perhaps be useful in obtaining data in support of electro-optical tests conducted for Army weapons systems."

The pattern established by these answers is quite clear. The first seven respondents all do atmospheric sampling at altitudes below 5000 ft. They all have immediate needs for which the mini-blimp and tethered balloon are very relevant platforms. The eighth person, Harold Ballard, requires altitudes up to 30,000 ft and the Mini-Sniffer is so relevant to his needs that his organization is currently developing a similar RPV. At lower altitudes he feels the tethered balloon would also be useful.

Considering the comments of all the survey participants in all of the user disciplines it is fair to conclude that, of all the proposed strawman platforms, the mini-blimp and the tethered balloon are the ones which satisfy the most immediate needs of the users.

FAA Regulations

The Federal Aviation Administration has many regulations on the use of pilotless aircraft. Several of the survey participants commented on these regulations either in their written replies or in follow-up telephone conversations. Some of them spoke from personal experience. While this area was not a formal part of the survey, the issue was raised often enough and is important enough to require that it be at least mentioned here.

The most specific comments were made by Hans Rudolph of Kennedy Space Center. He was preparing to use a tethered balloon on a 3000-ft cable at KSC when he was informed by the FAA that he would be required to place warning lights at 50-ft intervals along the cable. He calculated that the balloon would not support the weight of these lights. Further study of the published FAA regulations indicated to him that strobe lights at 500-ft intervals would meet the regulations and be technically feasible, but at this point he was informed that the FAA had decided that they could not permit him to fly his tethered balloon at all.

While the comments of other participants were not so specific as Mr. Rudolph's, several expressed general concern about whether the FAA would permit the use of tethered balloons or the mini-blimp in many areas, particularly urban localities where these platforms would be useful for pollution monitoring. Clearly these questions must be addressed before decisions can be made on development of any of the proposed platforms.

UTILITY RATINGS

Definite patterns emerge from the information presented in the previous pages. It is clear, for example that infrared astronomers would find the HAPP very useful and that the mini-blimp would be valuable for pollution monitoring. But these conclusions are qualitative. They do not answer such questions as how much more valuable one platform might be than another. To bring the survey results into sharper focus a numerical measurement scale has been applied to the comments given by each participant. This has made it possible to distill the results down to a single table which allows easy comparisons to be made among the platforms. A utility rating was assigned to each platform for each experiment. The scale is

0 = no utility
1 = low utility
2 = moderate utility
4 = high utility

If the overall comments of a particular experimenter make it clear that he judges that the HAPP, say, would be highly useful in his work, a 4 was assigned as his utility rating for the HAPP. If another experimenter had no use at all for the HAPP, then this platform was rated zero for him. If no judgment could be reached as to how a particular experimenter felt about the usefulness of a particular platform, no utility rating was assigned; however, this occurred in only a few cases. The non-linear scale used here weighs high utility more heavily than a linear scale (high utility = 3) would. This is judged to be appropriate since a highly useful platform is a great deal more valuable than one which rates only moderately useful.

In the process of analyzing the comments it became apparent that three new platforms should be defined. Each is a variation on one of the strawman platforms but sufficiently different from the strawman that it is useful to think of it as a separate platform. The strawman HAPP keeps station at a relatively fixed altitutde near 70,000 ft because this is a region of minimum wind velocities. Several of the astronomers said that the HAPP would be much more useful to them at higher altitudes. These experimenters fell into two groups, one desiring altitudes in the vicinity of 100,000 ft and the other desiring about 130,000 ft. Therefore, ignoring for the moment the question of technical feasibility, two new HAPPs were postulated, one keeping station at 100,000 ft and one at 130,000 ft. The air pollution monitoring community expressed a great deal of interest in the mini-blimp concept but many felt that the strawman mini-blimp's 90 to 130-lb payload was too small. Nearly all of the experimenters would be satisfied with a 500 to 600-lb payload, so a "heavy-lift" mini-blimp was postulated (a term which is somewhat whimsical but useful).

Table 7 lists the utility ratings resulting from analysis of the responses. Table 8 summarizes the numerical ratings. Ratings have been averaged over each discipline area. Overall ratings were not computed because the relative number of respondents in each discipline is not necessarily representative of the relative total number of scientists in that group. Furthermore, the averages are computed over only those respondents whose utility ratings are non-zero. No platform is suitable for everyone, and it would be misleading to lower the overall rating of a platform which has high utility in a specialized area by averaging in a large number of zeros from areas to which the platform is clearly not suited. So that the averaging technique used is not misleading in the other direction, the relative size of the group which finds a platform to be of substantial utility is indicated by showing the percentage of people in each discipline whose utility ratings are in the moderate to high (2 to 4) range. Thus for example, among low altitude atmospheric scientists, relatively few (13%) find the Mini-Sniffer of moderate to high utility but in this group the rating is very high (4.0).

Among the strawman platforms the strongest overall showing is made by the HAPP for astonomy; it has an average utility rating of 3.3 and nearly half the respondents rated it at least 2. Higher altitude HAPP's have higher average ratings among larger groups of astronomers. The feasibility of such platforms should definitely be further investigated.

If developmental technical risk and cost are taken into account the mini-blimp is the clear winner. It should be comparatively easy and inexpensive to develop and a heavy lift version scores at least 2 for 63 percent of the low altitude atmospheric scientists (in fact Table 7 shows that it rates 4 for half the respondents). The mini-blimp also makes a strong showing (2.8 and 27%) in the remote sensing community.

The Mini-Sniffer scores quite high (3.2) and captures a fairly significant fraction (27%) of the high altitude atmospheric science community.

The tethered balloon shows only moderate utility and the MADB has the smallest following of all the platforms.

TABLE 7. UTILITY RATINGS OF EACH PARTICIPANT

	Strawman HAPP	High Alt. HAPP (~100 kft)	Ultra High Alt. HAPP (~130kft)	Strawman Mini-Blimp	Heavy Lift Mini-Blimp (5-600lb Payload)	Strawman Tethered Balloon	Strawman Mini-Sniffer	Strawman HADB
Astronomy IR								
R. Weiss	0	2	4	0	0	0	0	0
G. Fazio	0	4	4	0	0	0	0	0
J. Houck	4	4	4	0	0	0	0	0
T. Kuiper	2	2	2	0	0	0	0	0
M. Mumma	4	4	4	0	0	0	0	0
H. Aumann	4	4	4	0	0	0	0	0
W. Hoffmann	1	1	4	0	0	0	0	0
W. Traub	0	2	2	0	0	0	0	0
Cosmic Rays								
J. Ormes	4	4	4	0	0	0	0	0
A. Tucker	4	4	-	0	0	0	0	0
M. Isreal	0	0	0	0	0	0	0	0
X-Ray								
G. Fishman	0	0	4	0	0	0	0	0
L. Peterson	0	0	-	0	0	0	0	0
C. Fichtel	0	0	-	0	0	0	0	0
Low Alt. Atmospheric Science								
B. Zak	0	0	0	1	4	0	0	0
E. Martinez	0	0	0	1	2	0	0	0
C. Fitzsimmons	0	0	0	1	1	4	0	0
D. Stedman	0	0	0	4	4	-	0	0
J. Armstrong	0	0	0	4	4	2	0	0
H. Rudolph	0	0	0	1	1	2	0	0
G. Gregory	0	0	0	1	4	-	0	0
H. Ballard	0	0	0	1	1	1	4	0

TABLE 7. (Continued)

	Strawman HAPP	High Alt. HAPP (~100kft)	Ultra High Alt. HAPP (~130kft)	Strawman Mini-Blimp	Heavy Lift Mini-Blimp (5-600lb Payload)	Strawman Tethered Balloon	Strawman Mini-Sniffer	Strawman MADB
High Alt. Atmospheric Science								
C. Farmer	0	-	-	0	0	0	0	0
K. Mauersberger	0	-	-	0	0	0	0	0
J. Rosen	4	-	-	-	0	0	4	2
N. Farlow	0	-	-	0	0	0	4	2
L. Megill	0	-	-	0	0	0	0	0
D. Hofmann	0	-	-	0	0	0	0	2
I. Poppof	0	-	-	0	0	0	0	0
M. Shumate	0	-	-	0	0	0	0	0
A. Schmeltekopf	0	-	-	0	0	0	0	2
S. Krimigis	0	-	-	0	0	0	0	0
D. Stedman	1	-	-	0	0	0	2	0
W. Traub	0	-	-	0	0	0	0	0
P. Kuhn	2	-	-	0	0	0	2	0
E. Sullivan	0	-	-	0	0	0	0	0
R. Thomas	0	0	4	0	0	0	0	0
J. Kumer	2	-	-	0	0	0	0	0
W. Cross	0	-	-	0	0	0	0	0
W. Berg	4	4	-	0	0	0	0	0
E. Reed	0	-	-	0	0	0	4	0
Remote Sensing								
S. Hsu/L. Rouse	2	-	-	2	-	2	2	2
O. Huh	4	-	-	4	-	0	1	4
D. Conley	0	0	0	0	-	0	0	0
J. Eckert	0	0	0	0	-	0	0	0
J. Milton	0	0	0	0	-	0	0	0
S. Levin	0	0	0	0	-	0	0	0
T. Gilbert	0	0	0	0	-	0	0	0
J. Schoolmeester	0	0	0	4	-	4	0	0
H. Rib	0	0	0	0	-	0	0	0
D. Lichy	0	0	0	2	-	2	0	0
L. Crook	0	0	0	0	-	0	0	0
W. Chapman	0	0	0	0	-	0	2	0
R. Ragan	0	0	0	0	-	0	2	0
W. Shaw	0	0	0	0	-	0	0	0
T. Jackson	0	0	0	0	-	2	0	0
D. Charter	0	0	0	0	-	0	0	0
T. Cunningham	0	0	0	0	-	0	0	0
T. Czuba	0	0	0	0	-	0	0	0
V. Noble	0	0	0	2	-	2	0	0

Note: Dash (-) appears where participants of utility opinion could not be judged from his response.

TABLE 8. MEAN UTILITY RATINGS BY DISCIPLINE

	Strawman HAPP (70kft)	High Alt. HAPP (-100kft)	Ultra High Alt. HAPP (-130kft)	Strawman Mini-Blimp	Heavy Lift Mini-Blimp (5-600 lb Payload)	Strawman Tethered Balloon	Strawman Mini-Sniffer	Strawman MADB
Astronomy and Astrophysics	3.3 43%	3.1 64%	3.6 71%	--	--	--	--	--
Low Altitude Atmospheric Science	--	--	--	1.8 25%	2.6 63%	1.8 38%	4.0 13%	--
High Altitude Atmospheric Science	2.6 22%	4.0 5%	4.0 5%	--	--	--	3.2 27%	2.0 22%
Remote Sensing of Earth's Surface	3.0 11%	--	--	2.8 27%	--	2.4 26%	1.8 16%	3.0 11%

(First number is the average computed over all respondents in each discipline who judged a platform to have at least some utility; i.e., non-zero. Second number is the percent of total respondents in each discipline who judged utility to be moderate or high (2 or 4).

Conclusion and Recommendations

A set of widely varied scientific and applications experiment requirements have been identified through this survey. By separating the individual requirements into three broad categories - atmospheric science, astrophysics, and remote sensing - some general requirements regarding these groups as a whole have been identified.

Atmospheric Sciences. This group is generally divided into two altitude interest regions: from the surface to 5000 feet, and above 40,000 feet. There is no distinction between groups in payload weight (less than 1000 pounds) or ground travel (less than 100 miles) requirements. For endurance the low altitude group required 4 to 5 days duration and the high altitude requirement was for up to one year.

Astrophysics. This group has a requirement for high altitude (70,000 feet or greater) and heavy payloads (1000 pounds or more). Stationkeeping is not critical for an astronomy platform so long as the platform stays within range of the ground station used for its telemetry system. Duration requirements are met with 10 day endurance capability for most users.

Remote Sensing. This group's region of interest is primarily below 10,000 feet altitude. Payload wights are less than 1000 pounds and mission durations of less than 10 days are required.

All in all the study has indicated that there are a number of presently unavailable, unmanned experiment platforms that could provide a variety of important uses to science and applications research programs. At a minimum, continuation of the study and development efforts currently being conducted for these platforms is indicated.

The requirements for two variations of the proposed platform strawmen were identified. These two - a heavy lift (500 to 600 pounds) mini-blimp and a higher altitude (100,000 to 130,000 feet) HAPP - represent new technology platforms, and as such, studies of their technical feasibility are indicated.

Although all platforms were shown to have some utility to this community, two of them stood out as having particularly high potential utility: the HAPP and the mini-blimp. The HAPP has definite potential as an astronomical platform for infrared and cosmic ray investigations. It also has potential, perhaps to a lesser degree, as a tool for upper atmospheric research and remote sensing.

The mini-blimp would be a very useful measurement platform for investigation of the source and propagation mechanisms of atmospheric pollution. It meets immediate needs of researchers in this field and if available would apparently be in use immediately. In addition, since a mini-blimp program would appear to have low technical risks with attendant low costs, a program to develop it and make it available for use by the scientific community is an extremely attractive proposition.

APPENDIX A

SURVEY PARTICIPANTS

APPENDIX A

SURVEY PARTICIPANTS

ATMOSPHERIC CHEMISTRY, PHYSICS AND POLLUTION MONITORING

James G. Anderson	Harvard
James A. Armstrong	U. of Denver
David Atlas	NASA - GSFC
Paul L. Bailey	NCAR
Harold Ballard	Army - ASL
Boyd Barker	U. of Denver
Charles A. Barth (Respondent: Ronald J. Thomas)	U. of Colorado
Albert E. Belon	U. of Alaska
Walter Berg	NCAR
Eugene W. Bierly	NSF
Charles Brunot	EPA
Moustafa T. Chahine (H.H. Aumann, listed under astrophysics, responded for self and Chahine)	JPL
W. F. Cross (Replied for self, W. Martin, P. Badgley)	Navy - ONR
Robert Curran	NASA - GSFC
Roger C. Dahlman	DOE
Douglas Davis	Georgia Tech.
Richard E. Davis (Respondents: G. Gregory, E. Sullivan)	NASA - LaRC

Neil H. Farlow	NASA - ARC
Crofton B. Farmer	Cal Tech.
Richard Goldberg	NASA - GSFC
Gerald W. Grams	Georgia Tech.
Paul B. Hays	U. of Michigan
Leroy Heidt	NCAR
E. David Hinkley (Respondent: M.S. Shumate)*	JPL
David J. Hofmann	U. of Wyoming
James R. Holton	U. of Washington
Robert Hudson (Respondent: Edith Reed	NASA - GSFC
S.M. Krimigis	Johns Hopkins U.
P.M. Kuhn	NOAA
John V. Kumer	Lockheed
Al Lazarus	NCAR
Walter Martin (Respondent: W.F. Cross - appears under remote sensing)	Navy - ONR
E. L. Martinez	EPA
Konrad Mauersberger	U. of Minnesota
David N. McNelis (Respondent: C.K. Fitzsimmons)	EPA
L. R. Megill	Utah State U.
Richard W. Munt	EPA
David G. Murcray	U. of Denver
Ted Pepin	U. of Wyoming

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* In some cases a data package sent to one person was passed to someone else for response.

Ilia G. Poppoff	NASA - ARC
James L. Raper	NASA - LaRC
James M. Rosen	U. of Wyoming
Hans W. Rudolph	NASA - KSC
James M. Russell	NASA - LaRC
Arthur L. Schmeltekopf	NOAA
Donald H. Stedman	U. of Michigan
Wesley A. Traub (appears also under Astrophysics)	Harvard
Steven Wofsy	Harvard
Bernard Zak	Sandia Labs.

REMOTE SENSING OF THE EARTH'S SURFACE

Peter C. Badgley (Respondent: W.F. Cross)	Navy - ONR
James S. Bailey (Respondents: S.A. Hse, O.K. Huh, J. Rouse)	NASA - ONR (Louisiana State U.)
W. S. Black	Coast Guard
Bruce Blanchard	Texas A & M
Donald L. Birkimer	Coast Guard
William M. Brown	ERIM
John G. Busavage (Respondent: T.S. Cunningham)	Coast Guard
B. Charter	Coast Guard
Alden P. Colvocoresses	USGS
Leonard Crook	Consultant

Joseph DiNunno	NUS Corp.
John Dunkle	Air Force
Tim Gilbert	EG & G Corp.
Karl Grodewald	Spectral Data Corp.
J. Heinz	Coast Guard
Tom Jackson	USDA
Anne Kahle	JPL
David E. Lichy	Army
S. Benedict Levin	George Washington U.
Donald Lowe	ERIM
David N. McNelis (Respondent: J. Eckert)	EPA
Vincent Noble	Navy - NRL
George Peace	ERIM
Robert T. Platt (Respondent: J. T. Milton)	Coast Guard
Robert M. Ragan	U. of Maryland
Harold Rib	Fed. Highway Admin.
John K. Schoolmeester	U.S. Customs
Russell L. Schweickart	State of California
David Simonette	U. of California Santa Barbara
Olav Smistadt (Respondent: W. H. Shaw)	NASA - JSC
Rupert B. Southard (Respondent: William Chapman)	USGS
Robert A. Summers	DOE
John Walker	DOE

Joseph W. Waters	JPL
Ken Williams (Respondent: D. Conley)	Coast Guard
Robert J. Wright	DOE

ASTROPHYSICS

Hartmut H. Aumann	JPL
Robert M. Cameron	NASA - ARC
Giovanni G. Fazio	Harvard
Carl E. Fichtel	NASA - GSFC
Gerald Fishman	NASA - MSFC
Carl M. Gillespie	NASA Hdq.
William F. Hoffman	U. of Arizona
Robert L. Golden	New Mexico State U.
James R. Houck	Cornell U.
Martin Israel	Washington U.
T.B.H. Kuiper	JPL
Frank J. Low	U. of Arizona
Dietrich Muller	U. of Chicago
Michael J. Mumma	NASA - GSFC
Jonathan Ormes	NASA - GSFC
Lawrence E. Peterson	U. California, San Diego
Paul Richards	U. California, Berkeley
George Ricker	MIT

Wesley A. Traub (appears also under Atmospheric Science)	Harvard
Alan B. Tucker	San Jose State U.
Ranier Weiss	MIT

PLATFORM MANUFACTURERS, OPERATORS AND TECHNICAL SPECIALISTS

Edward M. Arnold	T-COM Corp.
George Durney	ILC Industries
James F. Dwyer	Air Force Geophysical Lab.
Jon Eney	Navy LTA Program Office
T. Kelly	Air Force Geophysical Lab.
Vincent E. Lally	NCAR
James Luers	U. of Dayton
Walter H. Manning	Air Force - Patrick AFB Technology Division
Larry Martins	RCA Aerostat Systems
Donovan E. McGee	Sheddahl, Inc.
Nelder Medrud	NCAR
Jean R. Nelson	Winzen Research Co.
James C. Payne	Air Force Geophysics Lab.
James L. Rand	Texas A & M
Alfred Shipley	National Scientific Balloon Facility
Ira Steve Smith, Jr.	NCAR
James Winker	Raven Industries

APPENDIX B

INFORMATION PACKAGE

PROVIDED TO SURVEY PARTICIPANTS

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

December 22, 1978

Dr. Douglas Davis
Georgia Institute of Technology
School of Geophysical Science
Atlanta, GA 30332

Dear Dr. Davis:

With reference to our recent conversation, we are providing you with the enclosed information package.

Battelle is investigating user and mission requirements for unmanned airborne platforms for scientific and applications missions. The effort is being undertaken for the National Aeronautics and Space Administration's Wallops Flight Center (NASA Wallops) to determine both whether there exists a significant demand for new types of unmanned platforms, and also what are the potential user's needs with respect to the characteristics and capabilities of the platforms.

As part of NASA's effort to expand the range of aeronautical capabilities available for scientific and application experiment users, NASA is currently considering several types of devices for potential use as tools for the scientific and application experiment user community:

- Remotely Piloted Vehicles (Mini-sniffer and Mini-Blimps)
- High Altitude Powered Platforms (HAPP's)
- Tethered Balloons
- Mid-Air Deployed Balloons

Brief descriptions of these systems are included in the data package enclosed. The vehicles described should be regarded as straw-men; i.e., the parameters such as payload, attitude capability and endurance have not yet been firmly fixed. It must be emphasized that this list is not to be considered as exhaustive; additional user requirements which can only be met by other systems will be considered relevant to the study.

Referring to the data package enclosed, we are asking you to consider how you may be able to use an unmanned airborne platform in your current work or some extension thereof. If an unrelated application comes to mind, we would also appreciate your informing us.

Your interests and requirements are being requested to assist us in determining the representative needs of the scientific and application-oriented communities to provide the basis for evaluating the suitability and relative effectiveness of the proposed platforms and identifying new technology platform opportunities. The enclosed information contains a summary of the current concepts for these platforms and some questions and statements to assist you in crystallizing your thinking in terms of relating your needs to design criteria.

We recognize the inherent limitations of this type of request. Your estimates of future needs are expected to be tentative. Where there is uncertainty in your future requirements, we would be interested to know what factors contribute to this uncertainty. To assist in planning for these platforms we would also like to have your opinions on time phasing. For example, if you feel that future developments in measurement from space will make these airborne platforms obsolete for your purposes after a certain period, we would like to have your estimate of when this might occur. We would also appreciate comments on any other considerations not raised here which you feel are important.

If you have any questions about this material, please do not hesitate to call us at (614) 424-5107 with charges reversed. A rapid response is not expected, as we wish you to have time to consider the possibilities of using these platforms. As we discussed, it would be appreciated if you could return your written response in about ten days so that we can digest the information and call you to resolve potential misunderstandings. As we have indicated, we do not need long or involved responses, unless you feel such are necessary. Since we are trying to include as many concepts as possible, you should also not hesitate to call us if you subsequently find another potential application of these platforms. Please return the list of questions to:

Mr. J. R. Mc Dowell
Battelle Columbus Laboratories
505 King Avenue
Columbus, OH 43201

Sincerely,

Mark B Kuhner

Mark B. Kuhner
Space Systems and
Applications Section

MBK:ss

Low-Altitude Tethered Balloon Characteristics

Low-altitude tethered balloon systems are unmanned balloon systems operating at altitudes from a few hundred feet to approximately 15,000 ft above mean sea level. The balloons range in size from 1,500 cu ft to 500,000 cu ft. The smaller balloons can lift a few pounds to 1,000 ft and the larger balloons can lift several tons to very low altitudes and lesser amounts to higher altitudes. The balloon system consists of the balloon and its accessories, the tether, the ground support equipment including the winch, and the payload. The balloon usually has a self-contained power supply to drive the payload and the fans and blowers. The amount of fuel carried by the power supply usually limits endurance to one day. In some systems copper wires embedded in the tether cable carry power to the balloon; this extends endurance to about 7 days.

Characteristics of two tethered balloon systems capable of lifting comparatively heavy payloads to high altitudes are listed below.

Summary of Characteristics

	System 1	System 2
Balloon Weight (lb)	5,000	6,400
Volume (ft^3)	267,000	365,000
Payload Weight (lb)	1,100	3,700
Maximum Altitude (ft)	12,000	15,000
Size of Ground Crew	4	4
Endurance (days)*	1-7	1-7

* See discussion above.

Mid-Air Deployed Balloon Characteristics

The U.S. Air Force is developing procedures and hardware for deploying balloons from aircraft. A prototype system being tested by the Air Force Geophysics Laboratory is aimed at being able to carry a 200 lb payload at an altitude of 70,000 ft. Endurance would depend on whether the eventual operational system uses a zero pressure or superpressure balloon. The balloon, its payload and cryogenic hardware containing liquid helium to inflate the balloon are contained in a cannister which is dropped from an airplane at an altitude of 25,000 ft. A parachute slows the descent of the system while the balloon is being inflated. After inflation a second parachute carries the cryogenic unit to the ground and the balloon and payload rise to their operating altitude of 70,000 ft. Advantages of mid-air deployed balloons are a capability for quick reaction to special events and a capability for deployment over remote or impassable regions. The characteristics of the Air Force system are summarized below; however, the same technology could be used to provide other combinations of altitude and payload weight.

Summary of Characteristics

Balloon Volume	158,000 ft^3
Payload Weight	200 lb
Maximum Altitude	70,000 ft
Endurance	24-72 hr[(1)] 30 days or more[(2)]

(1) Zero pressure balloon

(2) Superpressure balloon

Mini-Blimp Characteristics

The mini-blimp can be thought of as a very small, unmanned version of the Goodyear blimp. It would be remotely piloted by an operator on the ground. Because it would stay aloft even if its engine failed, it would be extremely safe. It could fly at speeds as high as 60 mph or hover stationary over a fixed point. A prototype of such a vehicle has been built and flown by Developmental Sciences, Inc. Characteristics of a typical mini-blimp would be approximately as shown below.

Summary of Characteristics

Vehicle Weight	500 lb
Volume	5000 ft^3
Payload Weight	90–130 lb
Maximum Altitude	2000 ft
Maximum Endurance	18 hr

High Altitude Powered Platform (HAPP) Characteristics

The High Altitude Powered Platform (HAPP) is presently in the early conceptual stage. Two preliminary studies of the HAPP have been carried out for NASA. Stanford Research Institute (SRI) analyzed the technical feasibility of the concept and Battelle Columbus Laboratories studied potential applications. The HAPP would use an electric motor-driven propeller to keep station against the wind. It would remain above a fixed point on the ground. Power would be supplied by microwave energy beamed from a ground station directly below the vehicle. To minimize the power required, the HAPP would fly in the region of minimum wind velocities. Over the continental United States this means a nominal altitude of about 21 km (70,000 ft).

The HAPP concept actually encompasses two distinct types of platforms. One is an airship (basically a large blimp); the other is a powered glider aircraft which would fly in a circle above the microwave transmitting station on the ground. Either vehicle could stay continuously on station for a year or more. The microwave system must supply a great deal of power for propulsion and the additional power required by almost any conceivable scientific payload would represent only a small fraction of the overall requirement; therefore, the amount of electrical power that would be available for the payload is very high for either concept. The SRI study of the HAPP concentrated on four HAPP concepts with payloads up to 1,600 lb; however, the study indicates that payloads of 8,000 lb to 10,000 lb or even more should be possible. Characteristics of the four concepts examined in the SRI study are summarized below.

Mini-Sniffer Characteristics

Remote Piloted Vehicles (RPV's) are unmanned aircraft controlled from the ground by radar tracking and/or by telemetry from on-board instruments and TV cameras. The Department of Defense has been developing RPV's for various military missions over a period of many years. NASA has recently developed an RPV especially for civil applications. While military RPV's tend to use very sophisticated avionics and are consequently quite expensive, the emphasis in the NASA design has been on simplicity and economy. Known as the Mini-Sniffer, the NASA RPV was developed originally as an atmospheric survey aircraft for sensing turbulence and measuring atmospheric constituents. It can carry a payload of 70 lb to an altitude of 20,000 ft or 25 lb to as high as 100,000 ft. Endurance is 3 hours. Propulsion is supplied by a large propeller at the tail of the aircraft. The powerplant is a hydrazine monopropellant engine. In this type of engine liquid hydrazine is expanded into a hot gas by passing it over a catalyst. The expanding gas drives a piston connected to the propeller shaft. The Mini-Sniffer represents a very cost-effective solution to the problem of combining the flexibility of operation of aircraft with the altitude capability of balloons.

Summary of Characteristics

Vehicle Weight	200 lb
Wingspan	18 ft
Payload Weight	25 to 70 lb
Maximum Altitude	20,000 ft for 70 lb 100,000 ft for 25 lb
Maximum Endurance	3 hr

Summary of Characteristics

	Small Airship	Large Airship	Small Airplane	Large Airplane
Platform Weight (lb)	1900	4800	1800	4500
Volume (ft^3)	0.5×10^6	1.3×10^6	--	--
Wingspan (ft)	--	--	98	98
Payload Weight (lb)	300	1600	300	1600
Altitude (ft)	70,000	70,000	70,000	70,000
Endurance (years)	1	1	1	1

INFORMATION PACKAGE

A. Personal Identification

1. Name______________________________ Telephone No. (   )________

2. Institution________________________

3. Mailing address

B. Areas of Technical Interest

1. What is your field of work?

2. (a) What would you be able to do in your field of work if one or more of the proposed airborne platforms were available to you that you can not do with currently available equipment such as aircraft and balloons? (General and brief description.)

(b) Can you place a measure of value on the improvement in capability provided by the new platforms?

(c) Do you consider that there is a growing need for effective and economical airborne measurement platforms?

Near Term (<5 years)________ Far Term (>5 years)________

(d) What new methods or mission alternatives do you desire?

(e) Are additional and/or unique capabilities needed to augment and enhance existing techniques?

(f) How suitable are existing platforms for your requirements?

(g) How suitable are the proposed platforms to meet your requirements?

(h) What major characteristics of currently available platforms limit or prevent their use in this application? If cost is a major limitation, please indicate the upper limit of cost per unit of time which you would consider feasible or acceptable.

3. (a) What potential application(s) do you foresee in areas not directly related to your current work?

(b) Who would be an appropriate person to contact about this (these) other applications?

C. Technical Requirements (please use separate sheets for each concept.)

1. Experiment Description or Equipment Purpose (Application)

2. Please supply your estimate of the following requirements for your equipment.

(a) Altitude most desired is ___________feet, with an acceptable range being from _________feet to _________feet.

(b) Ground travel range desired is ____________miles with a minimum of ________miles required.

(c) The direction of viewing interest is _____up
_____down
_____horizontal
_____oblique sky
_____oblique ground
_____in situ

(d) The desired duration of a flight is __________days. The minimum required duration is _________days.

(e) The desired availability year is 19___. The earliest useful year is 19___. The latest useful year is _____.

(f) The gross payload weight (including power supply, consumables and shock vibration mounting) desired is _______lbs. The minimum acceptable gross payload weight is considered to be ______lbs, and the maximum expected weight is ____lbs.

(g) The gross payload is expected to have the following approximate dimensions:

______inches x ______inches x _____inches if approximately rectangular. OR, the payload is expected to have the following approximate dimensions if not rectangular:

The expected range of maximum and minimum dimensions is:

(h) The payload is expected to require approximately _____ watts average power and _____ watts of peak power. A power supply provided by the platform would be necessary. __________ Desirable __________. (Yes/No, as appropriate.)

The expected range in power requirements is:
Peak Power: __________ watts Average Power: __________ watts.

(i) Other payload constraints on the platform are:
_________ shock vibration _________ electromagnetic interference
_________ pointing stability ______________________________ other.

(Please provide a quantitative estimate if available.)

3. Other Information Constraining Platform Design.

Your Comments. (Use additional sheets if necessary.)