

Outstanding Venus Science Questions

1. Explanation of the superrotation

- Zonal Flow
- Meridional Flow
- Physics of the polar vortex

2. Chemistry of sulfur, chlorine and compounds in relation with surface

3. Preparation for sample return

Will need aerostats

OUTSTANDING VENUS SCIENCE QUESTIONSA - GENERAL CIRCULATION (CONTINUED)

- 1/ WHAT IS THE LATITUDINAL VARIATION OF THE ZONAL FLOW ?
- 2/ WHAT IS THE LONGITUDINAL BEHAVIOUR OF THE ZONAL FLOW AFTER THE SUBSOLAR POINT ?
- 3/ WHAT IS THE CAUSE OF THE JET WHICH OCCURS PERIODICALLY AT MID TO POLAR LATITUDES ?
HOW DOES IT AFFECT THE OVERALL MOMENTUM BUDGET OF THE FLOW ?
- 4/ WHAT PROCESSES PRODUCE THE DECLINE OF THE ZONAL FLOW WITH INCREASING ALTITUDE ABOVE THE CLOUDS ?
- 5/ WHAT ROLE, IF ANY, DOES DISSIPATION PLAY IN THE DEGRADATION OF THE RAPID ZONAL FLOW ?
WHAT IS THE ROLE AND DISTRIBUTION OF SMALL SCALE TURBULENCE ?
- 6/ DOES CONVECTION PLAY AN IMPORTANT ROLE ? IF SO, WHERE ?
- 7/ ARE WAVES AND EDDIES THE CONTROLLING FACTORS IN THE RAPID FLOW?
WHAT ARE THE DOMINANT SCALES OF WAVES AND EDDIES ?
- 8/ WHAT ARE THE VALUES OF THE VERTICAL AND HORIZONTAL MOMENTUM FLUXES AT DIFFERENT LATITUDES AND ALTITUDES ABOVE AND BELOW THE CLOUD TOP MAXIMUM WINDS ?
- 9/ WHAT ARE THE RELATIVE FRACTIONS OF MOMENTUM AND HEAT TRANSPORT BY WAVES AND BY THE MEAN MERIDIONAL FLOW ?
- 10/ WHAT IS THE BEHAVIOUR OF AIR MASSES IN THE ZONAL FLOW ?

OUTSTANDING VENUS SCIENCE QUESTION

B - COMPOSITION

- 1/ WHAT IS THE CHEMISTRY OF SULFUR IN THE UPPER ATMOSPHERE OF VENUS ?
WHAT IS THE SOURCE OF SULFUR IN THE ATMOSPHERE AND HOW IS SO_2 OXIDIZED TO H_2SO_4 ?
ARE THERE ANY REDUCED FORMS OF SULFUR IN THE UPPER ATMOSPHERE ?
- 2/ CAN THE SULFUR CHEMISTRY BE USED AS AN INDICATOR OF VOLCANIC ACTIVITY ON VENUS ?
CAN THE DISTRIBUTION OF SULFUR SPECIES BE USED TO INFER VOLCANIC SOURCE LOCATIONS ?
- 3/ WHAT IS THE CHEMISTRY OF CHLORINE IN THE UPPER ATMOSPHERE OF VENUS ?
IS A CHLORINE INTERMEDIATE INVOLVED IN THE OXIDATION OF CO TO CO_2 ON VENUS, IN A MANNER SIMILAR TO THE WAY IN WHICH CHLORINE IS INVOLVED IN THE DESTRUCTION O_3 IN THE EARTH'S UPPER ATMOSPHERE ?
IS THE PRESENCE OF EXCESS HCL OR HF A BETTER INDICATION OF VOLCANIC ACTIVITY THAN SO_2 ?
- 4/ ARE THERE ANY VOLATILE METALLIC COMPOUNDS PRESENT IN THE UPPER ATMOSPHERE AS THE RESULT OF VOLCANIC ATIVITY ON THE SURFACE ?
- 5/ WHAT ARE THE PRECISE ABUNDANCES OF THE RARE GASES NE , AR , KR AND KE AND THEIR ISOTOPE ABUNDANCES ON VENUS ?
- 6/ WHAT IS THE D/H RATIO ON VENUS ?
- 7/ WHAT ARE THE ABUNDANCES OF TRACE OXYGEN SPECIES SUCH AS O_2 & H_2O ?

THE WAY TO A BREAKTHROUGH IN UNDERSTANDING
THE ATMOSPHERE OF VENUS

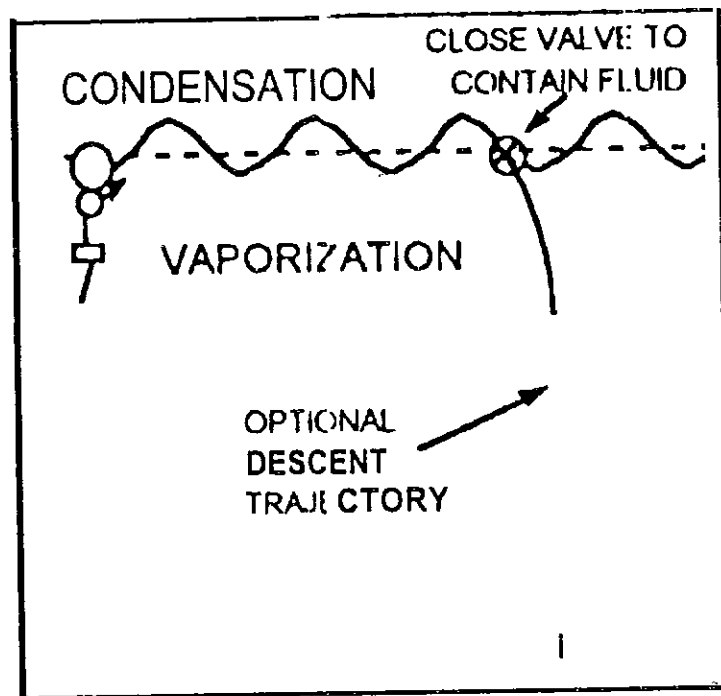
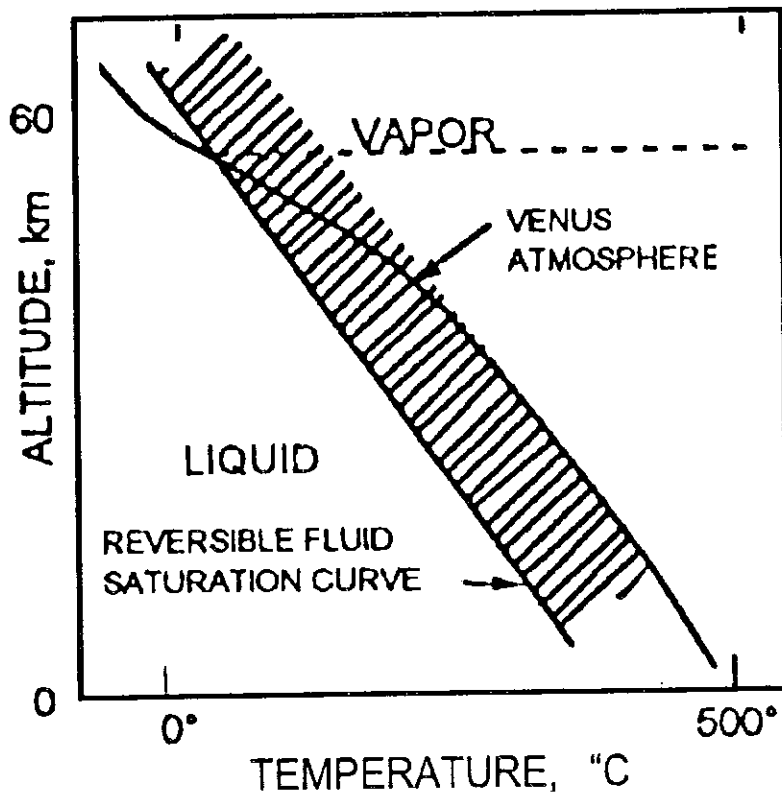
- 1 - LONG LIVED BALLOON AT CLOUD LEVELS MEASURES THE ATMOSPHERIC PARAMETERS FROM 55 KM TO GROUND BY A SERIES OF DROPSONDES
- 2 - STABLE PART OF THE ATMOSPHERE PROBED BY SMALL BALLOONS WITH VERTICAL EXCURSIONS
- 3 - UNKNOWN PART OF ATMOSPHERE AT HIGH ALTITUDE EXPLORED BY LONG LIVED BALLOON AT 65 KM COULD CARRY A M.S. FOR CHEMISTRY
- 4 - UNKNOWN PART OF ATMOSPHERE AT LOW ALTITUDE EXPLORED BY HIGH TEMPERATURE BALLOON AT 17 KM SHOULD GIVE EVIDENCE FOR DEEP HADLEY CELL

FUTURE BALLOON MISSIONS

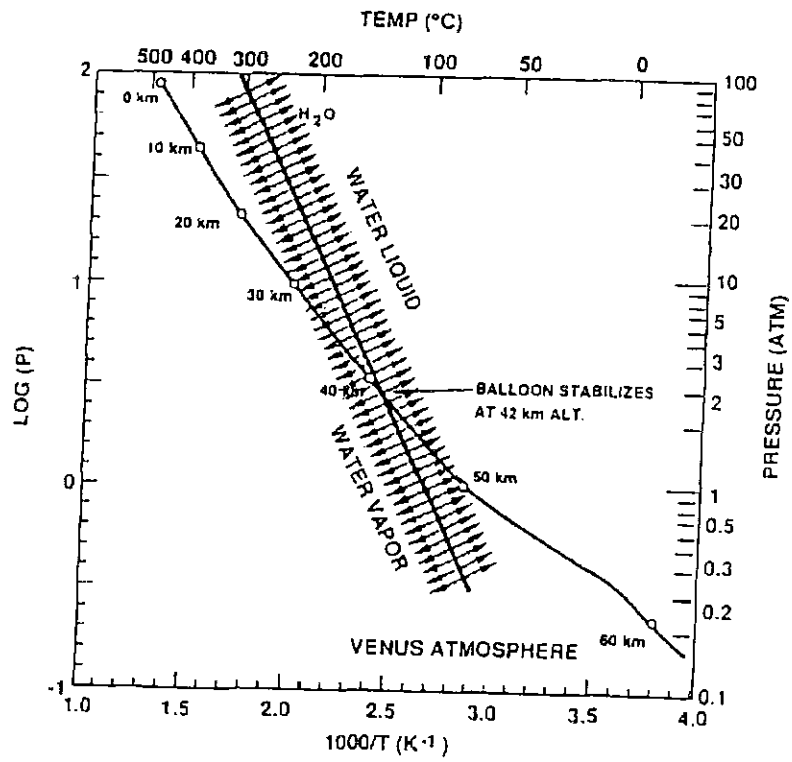
ADDRESSING THE VENUS SUPERROTATION PROBLEM

- WANT MANY (~ 12) PROFILES OF ($T, P, U, V, W, \sigma_{\text{CLOUD}}, F_{\text{VIS}}, F_{\text{IR}}$) FROM 40 TO 80 KM AT ALL (\sim EVERY 3°) LONGITUDES.
- TO GET THIS COVERAGE, NEED LONG-LIVED BALLOON CAPABLE OF CHANGING ALTITUDE, NAVIGATE ON GYROS, STORE TELEMETRY, MEASURE T, W WITHOUT WAKE EFFECTS.
- NON-EQUATORIAL COVERAGE (10° TO 30°) PLUS HIGH LATITUDE ($> 60^\circ$) IS DESIRABLE.
- MULTIPLE CIRCLING AROUND PLANET IS DESIRABLE.
- THIS MISSION WILL MEASURE THE LARGE-SCALE EDDIES, BOTH TIDAL (AND SYNOPTIC).
- THE SAMPLING WILL BE LIMITED (ONE EDDY EVERY FEW DAYS) BUT ADEQUATE.
- CAN DEFINE FLUXES OF HEAT + MOMENTUM, BOTH VERTICAL + HORIZONTAL, AND MEAN CIRCULATION.

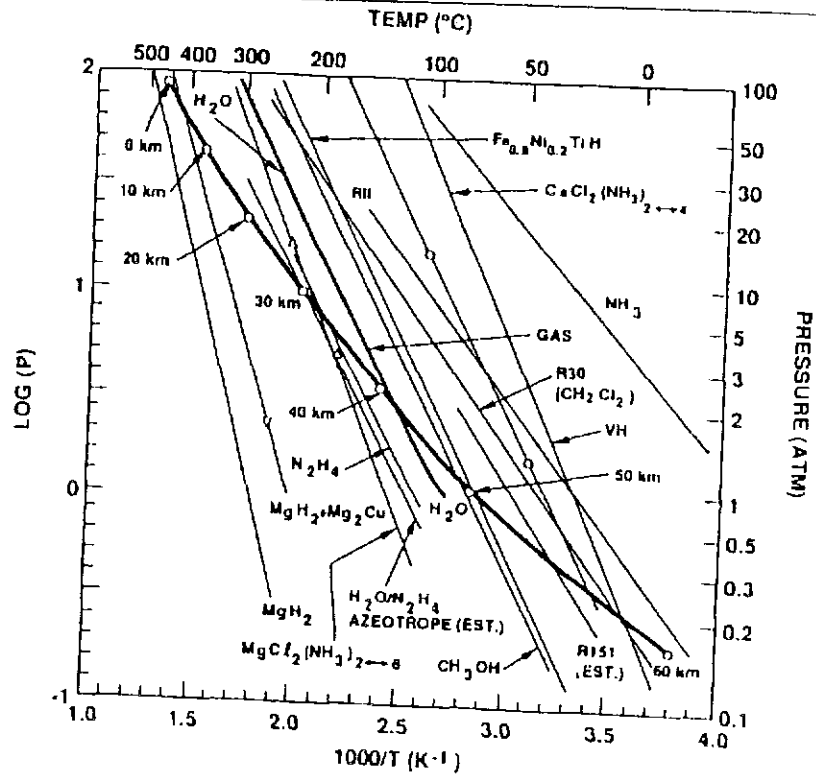
ALTITUDE STABILIZATION USING REVERSIBLE FLUID



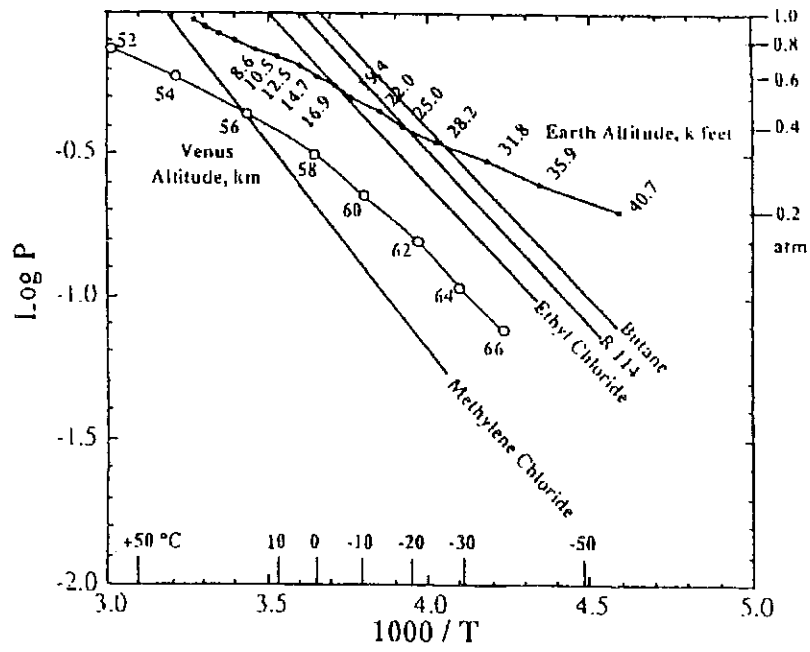
Venus Balloon Equilibrium Altitude and Cyclic Motion



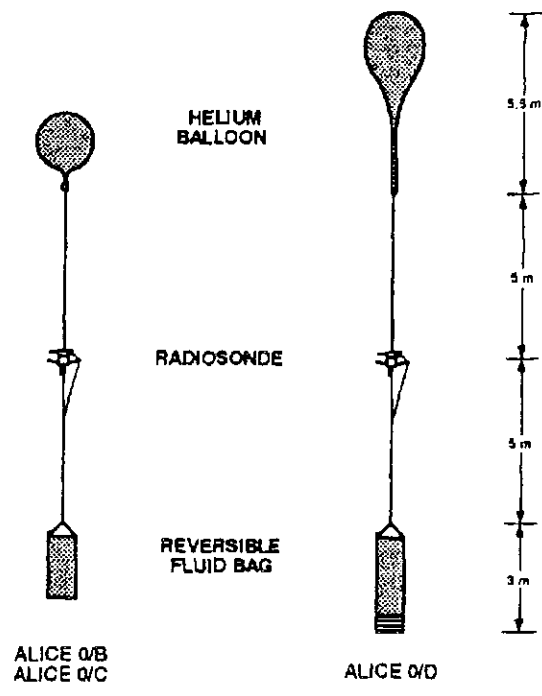
Van't Hoff Plot of Water and Venus Atmosphere.



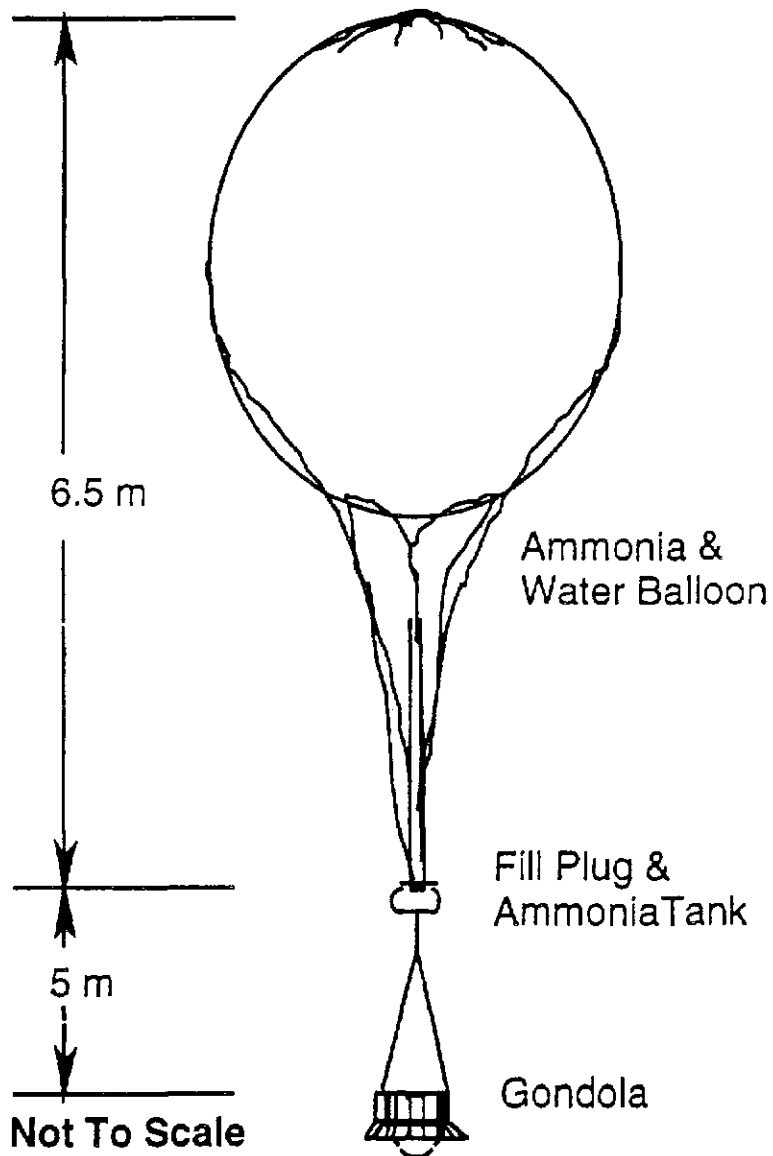
Van't Hoff Plots for Reversible Fluids.

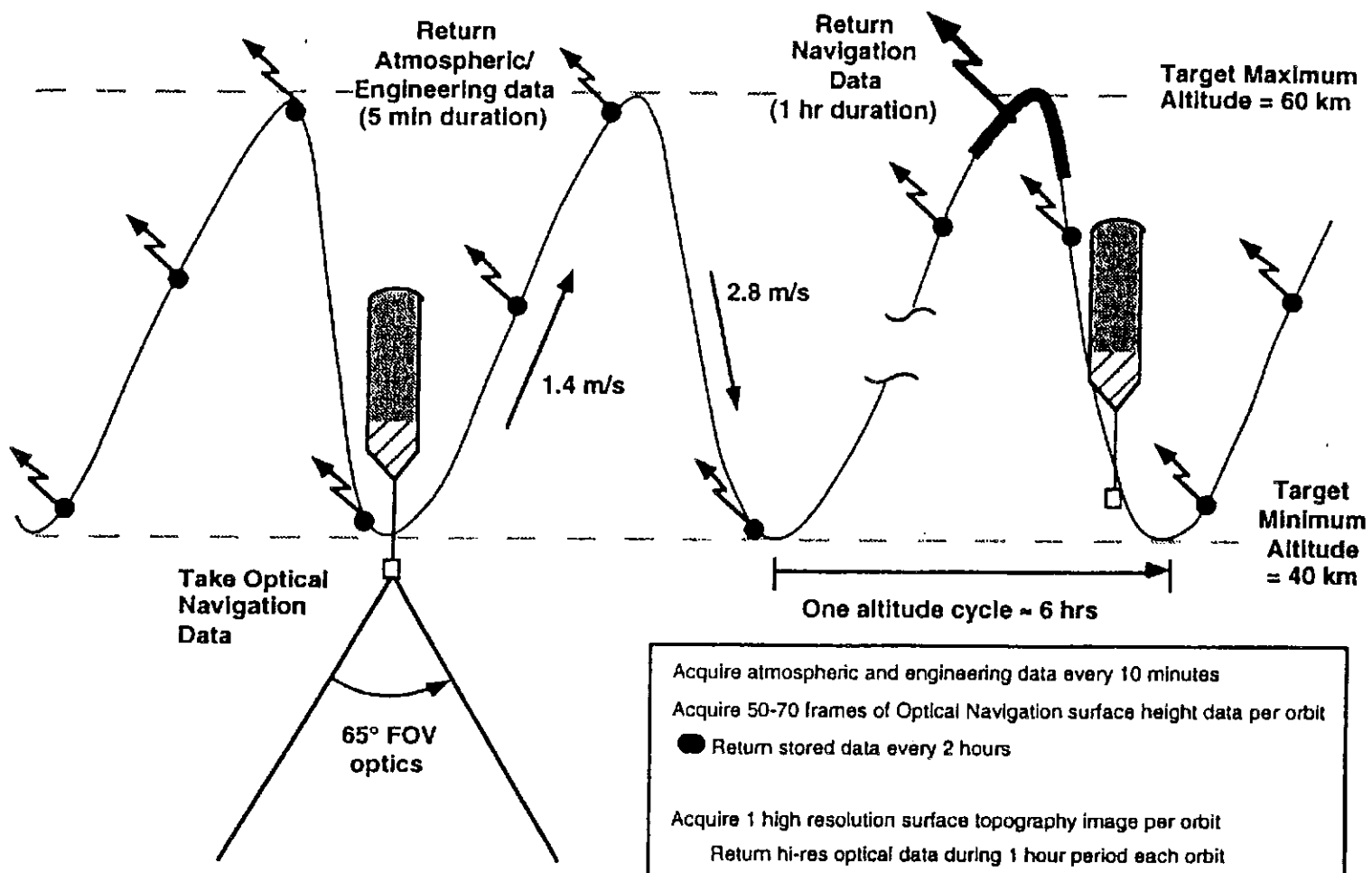


Van't Hoff Plot for Fluids at Earth and Venus

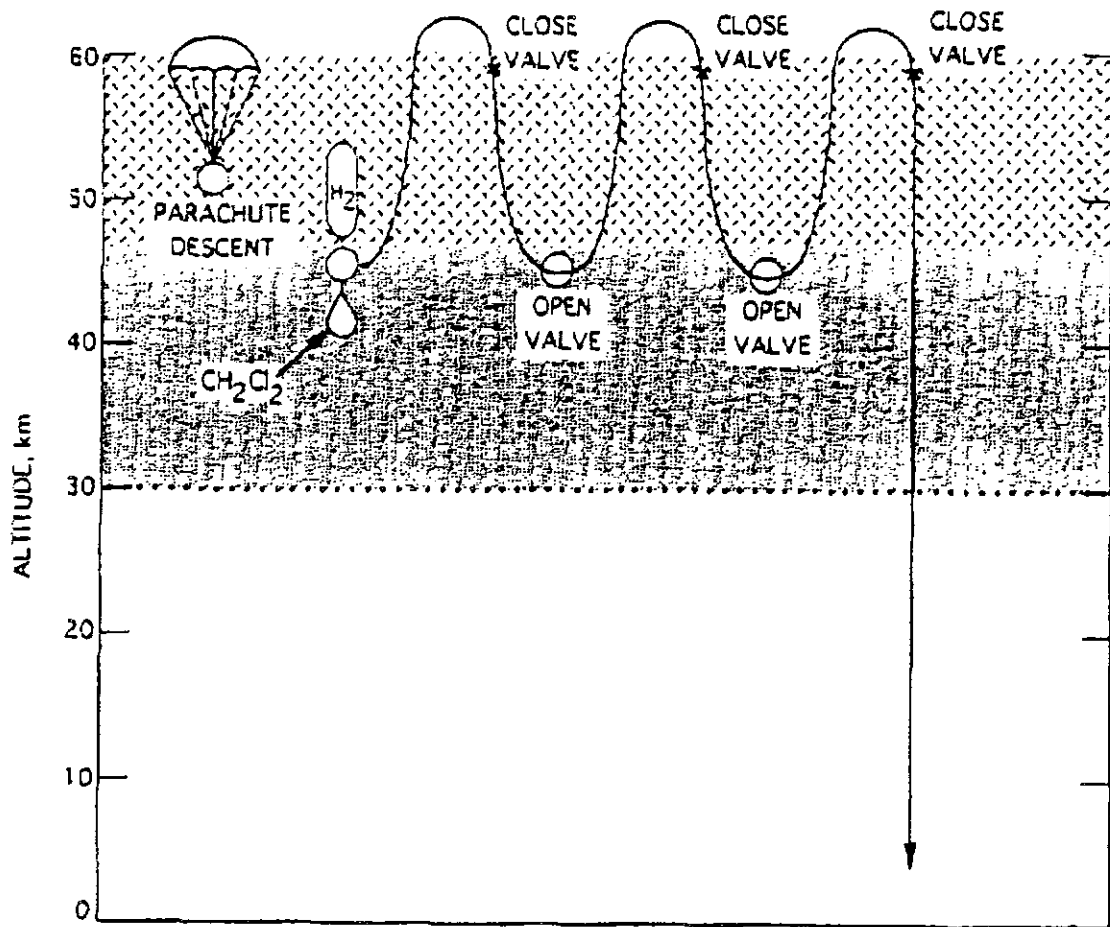


Attitude control experiment balloon system.

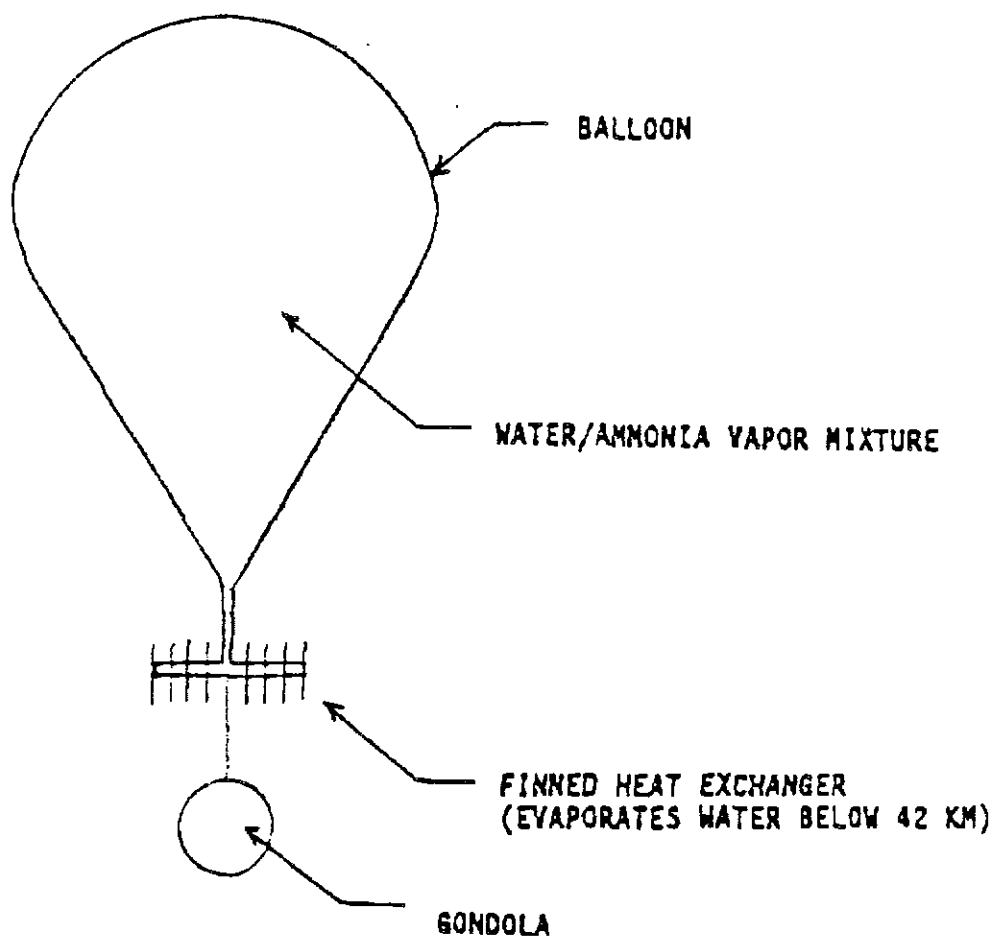




- Acquire atmospheric and engineering data every 10 minutes
- Acquire 50-70 frames of Optical Navigation surface height data per orbit
- Return stored data every 2 hours
- Acquire 1 high resolution surface topography image per orbit
- Return hi-res optical data during 1 hour period each orbit



Venus Cloud Bobber Mission Profile.



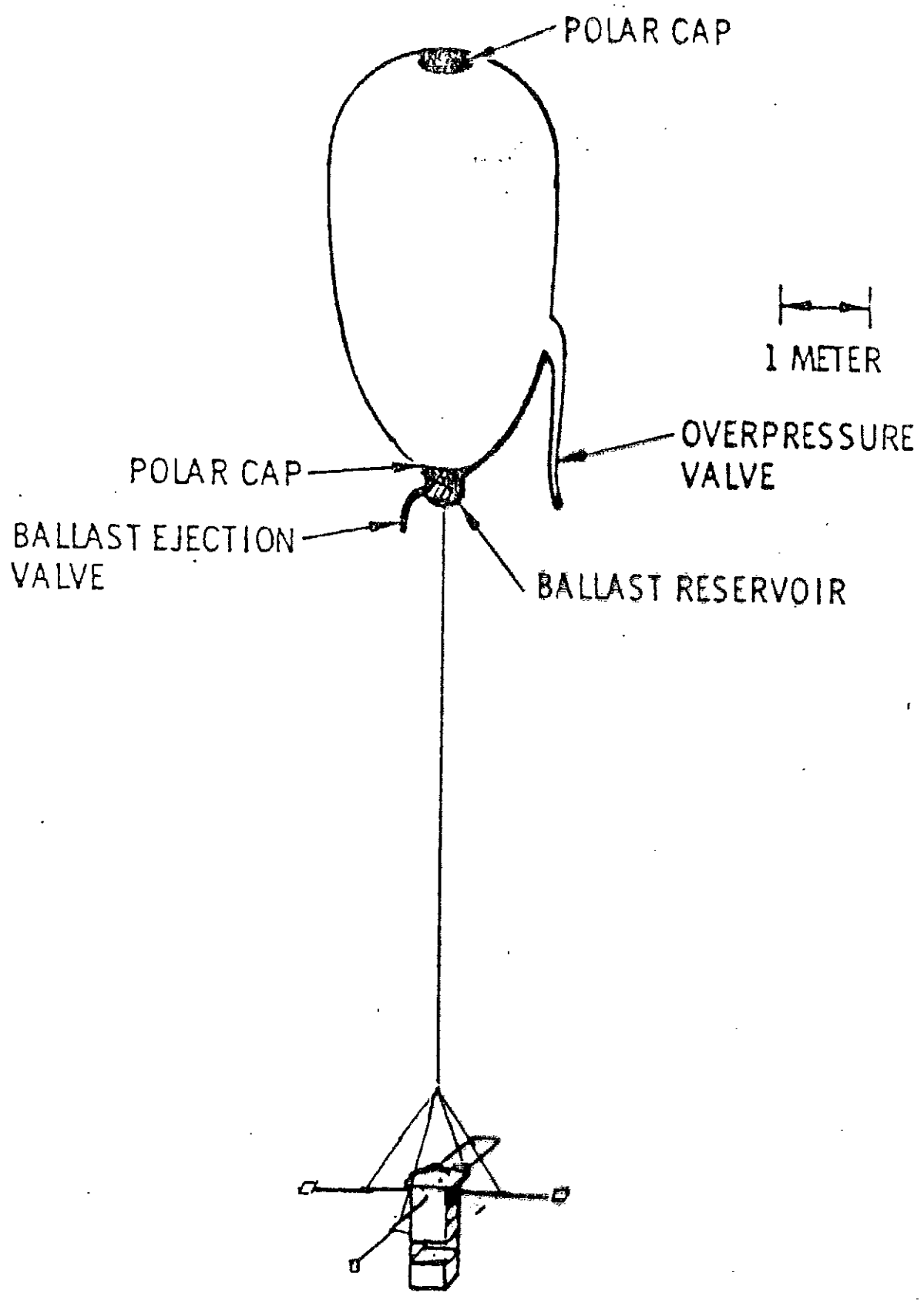
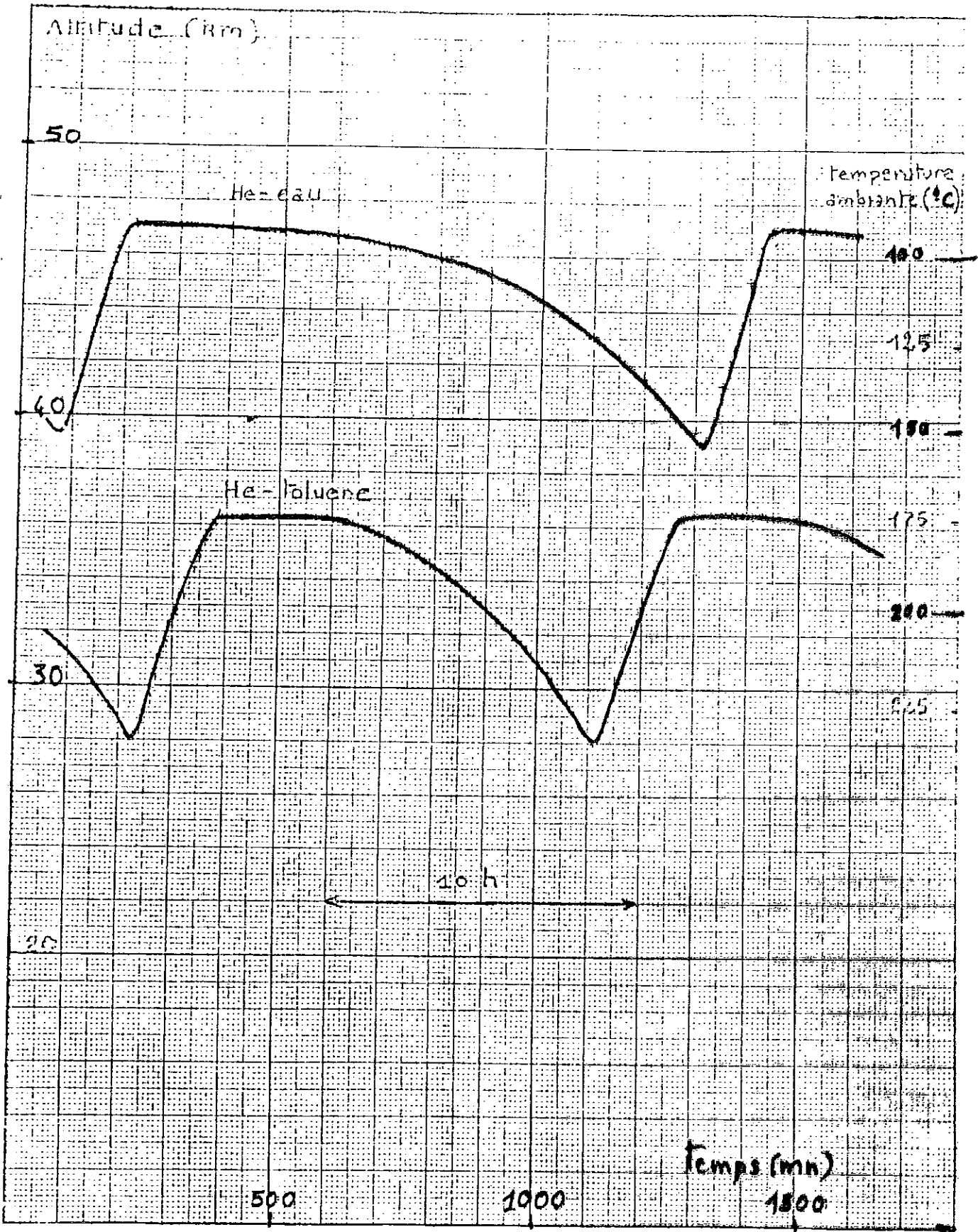
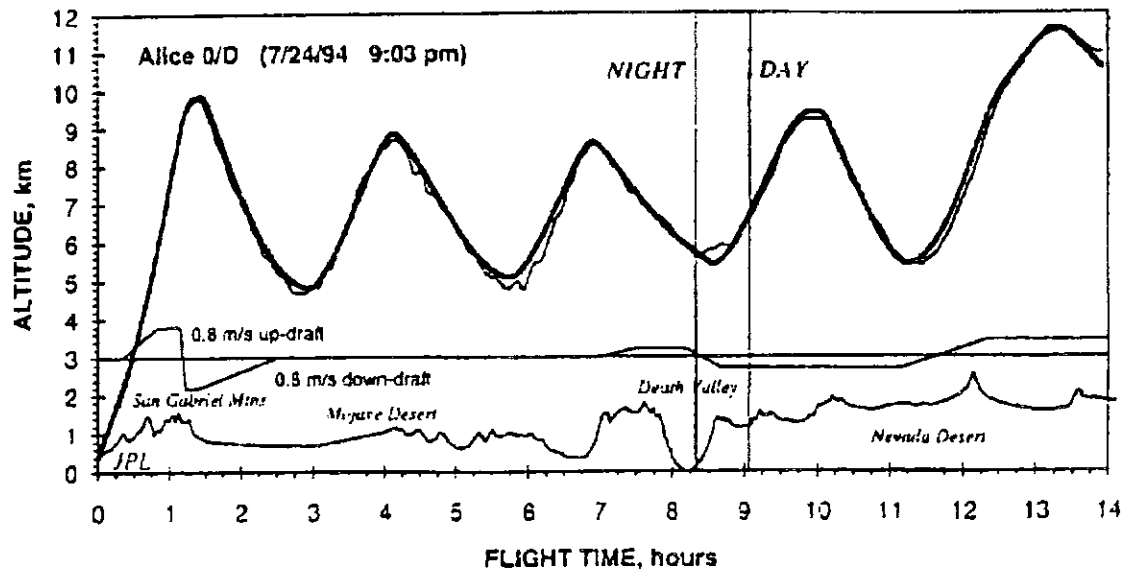
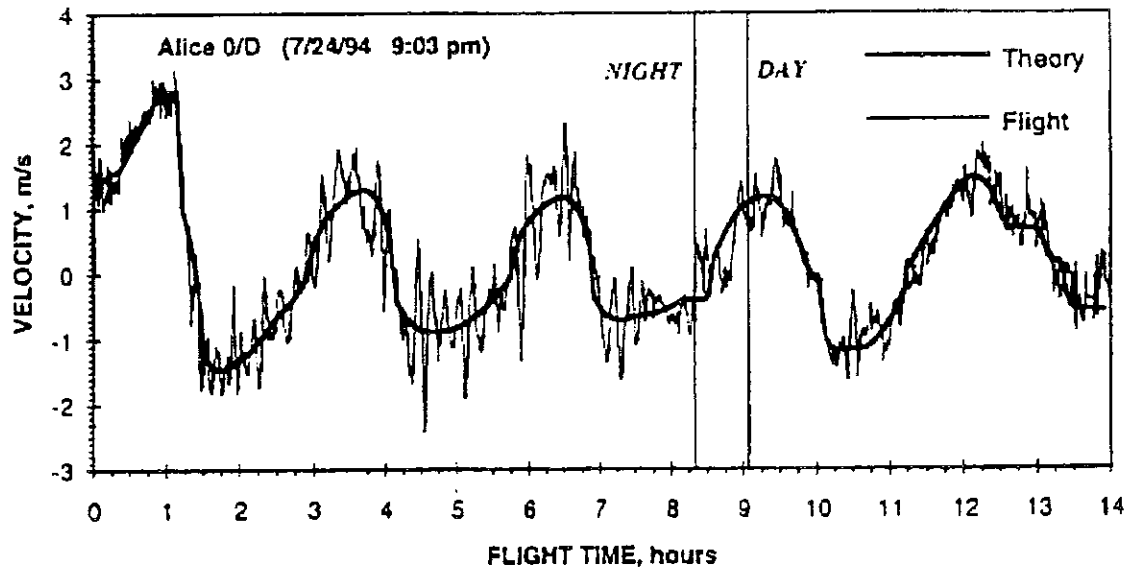


Figure 2. Sketch of a possible "lukewarm" balloon for operation near 40 km altitude.



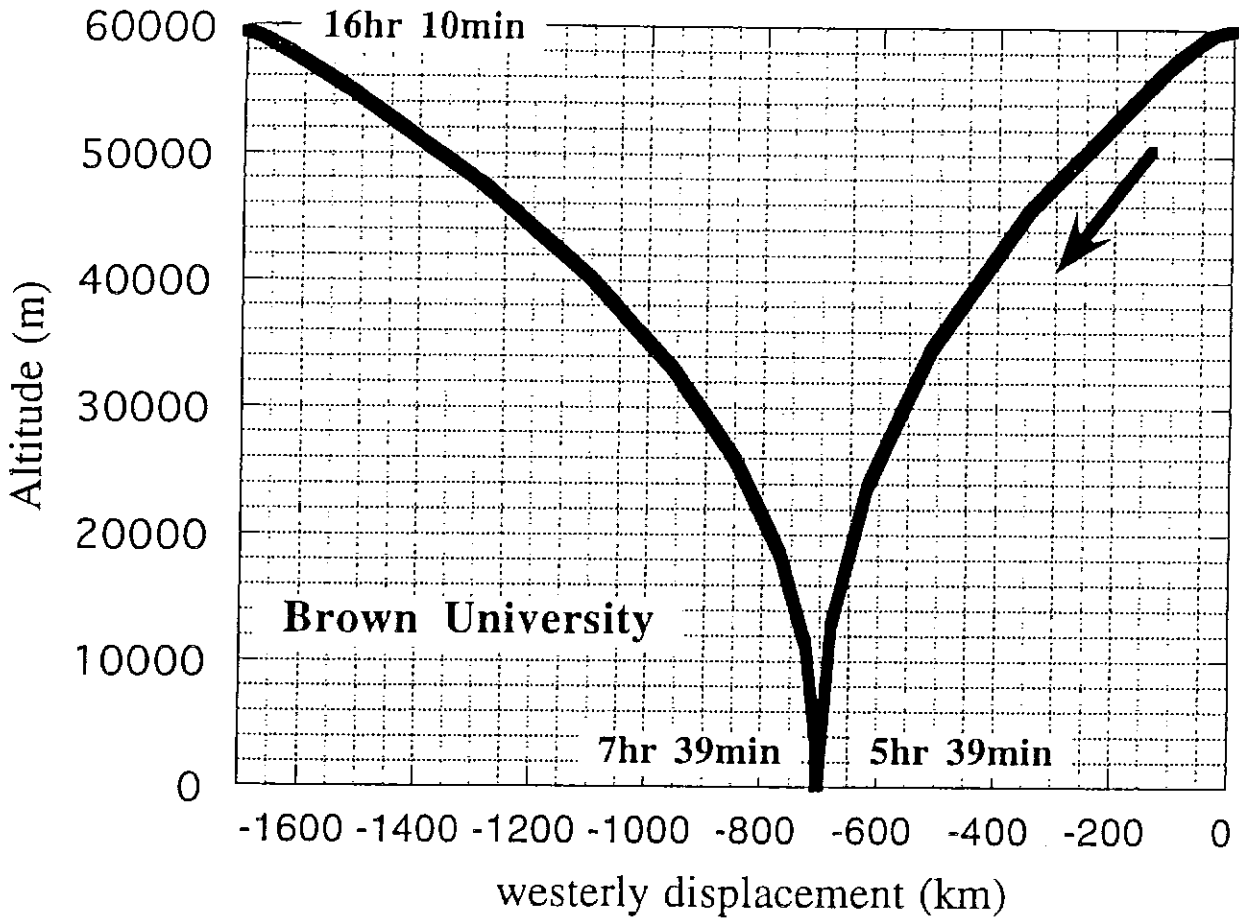


ALICE O/D altitude vs time

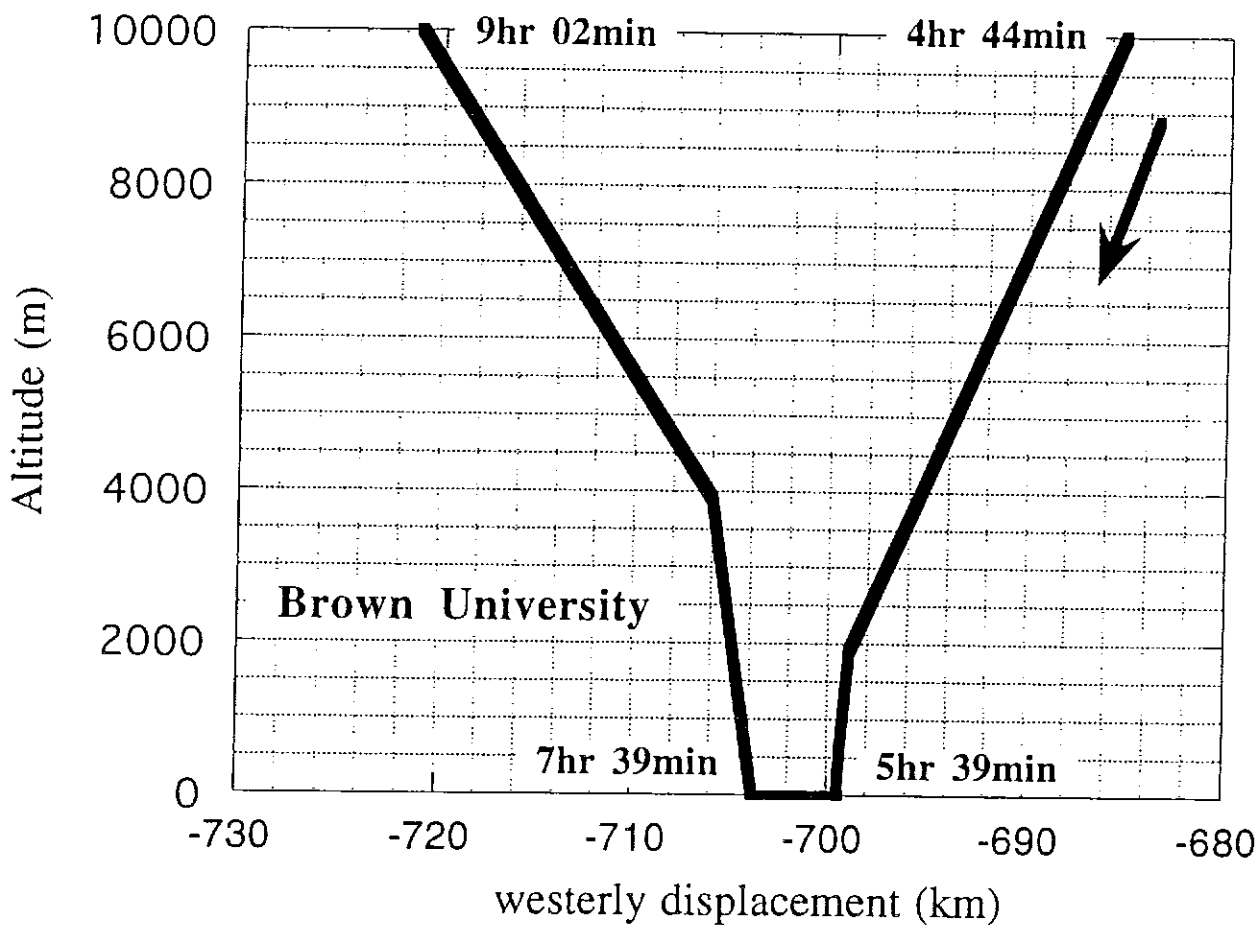


ALICE O/D velocity vs time

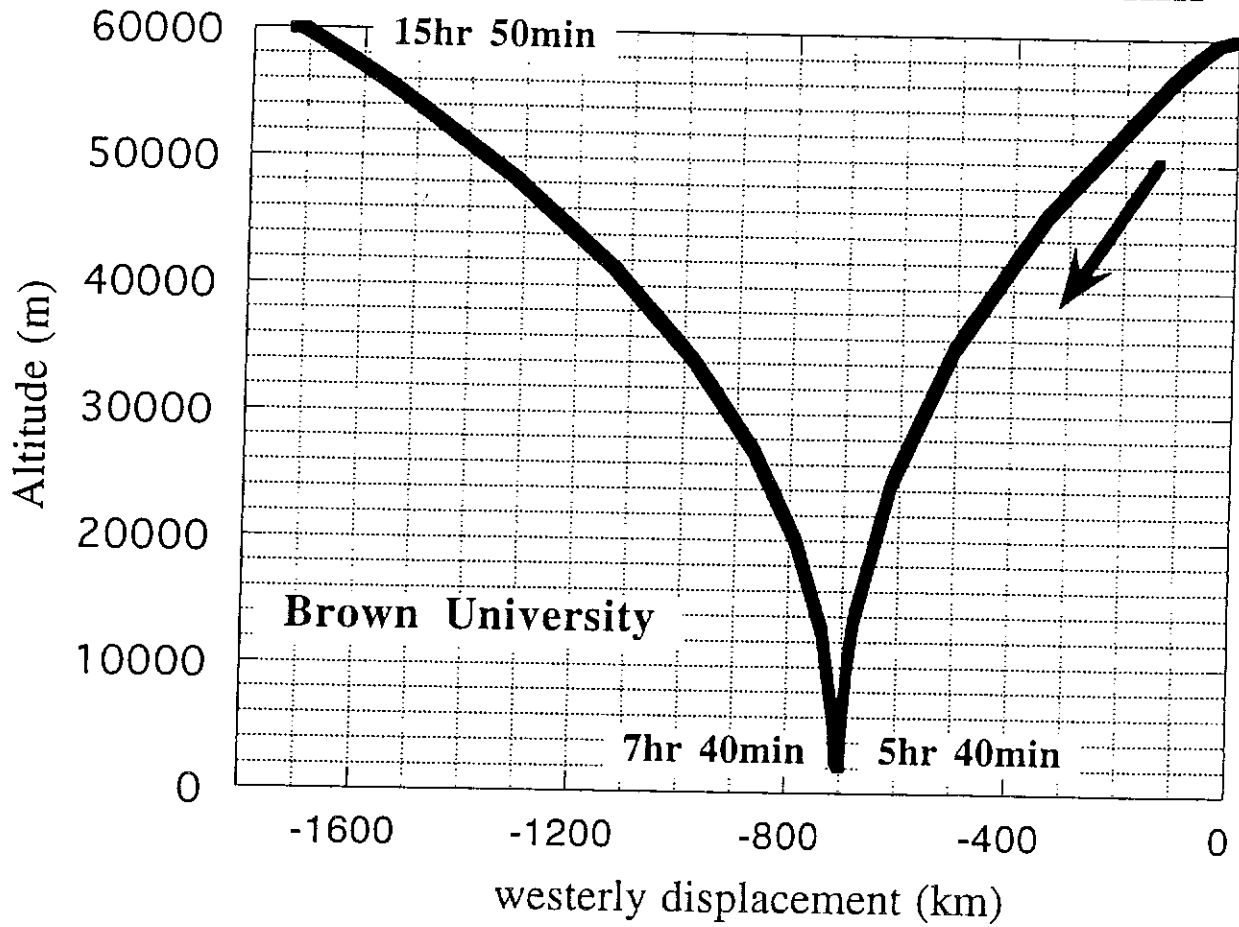
VFR Surface Dive



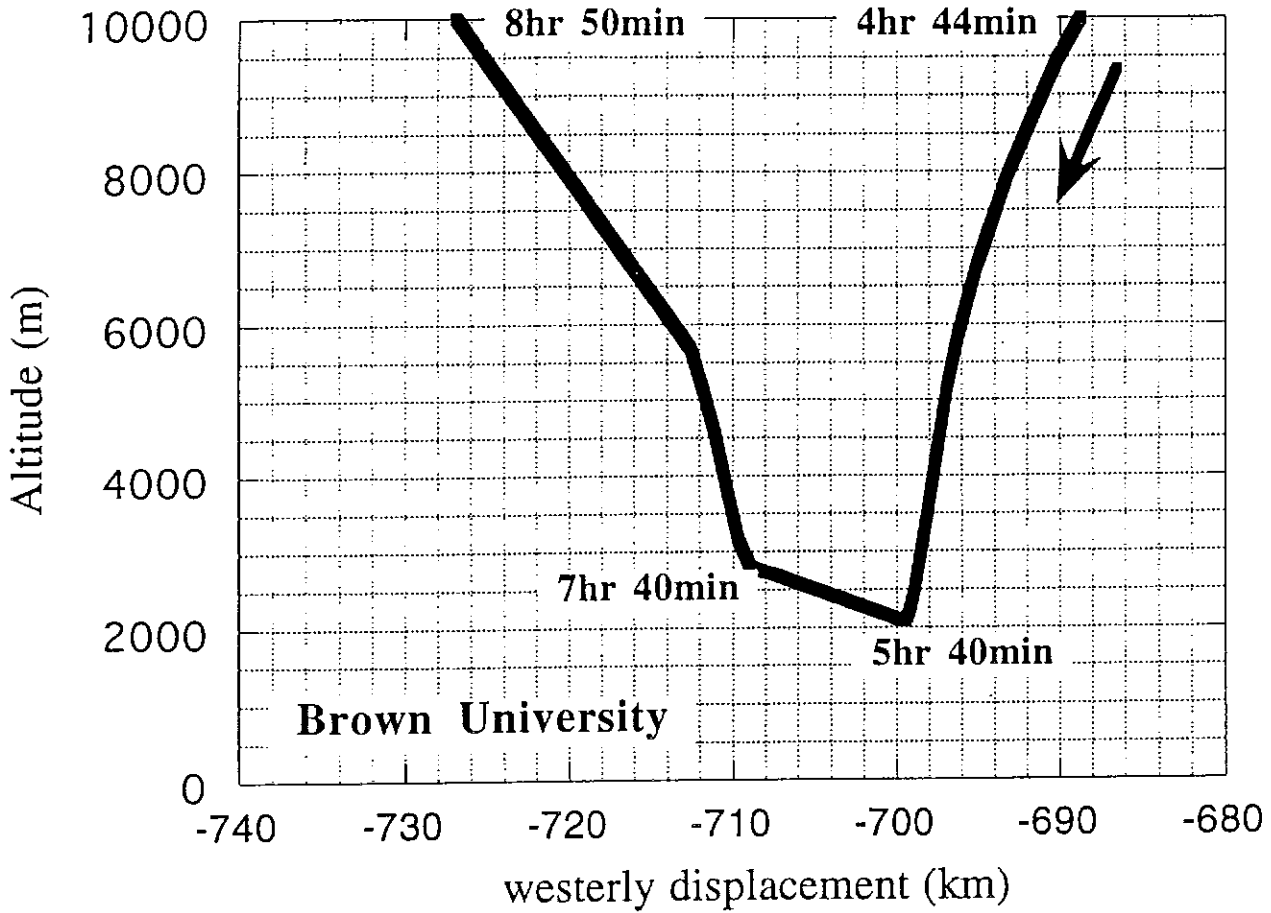
VFR Surface Dive



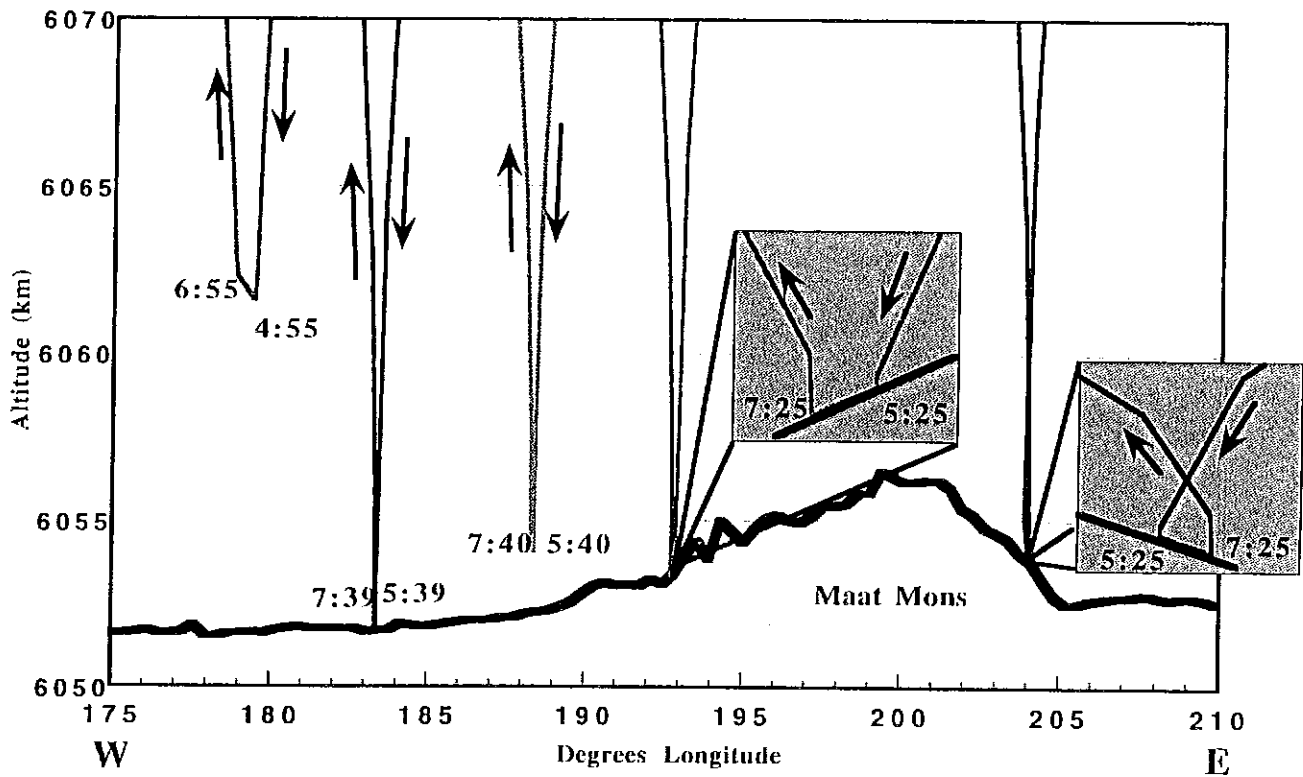
Stabilization at 2 km

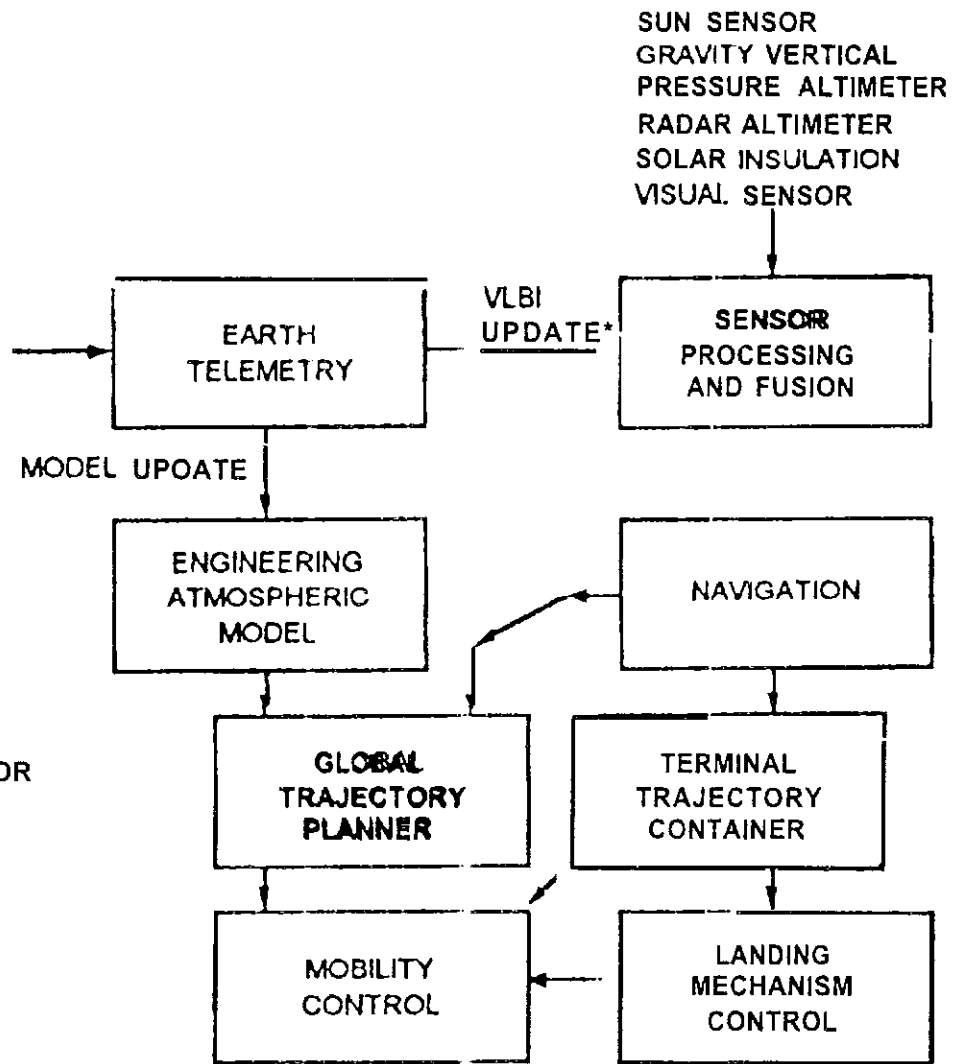
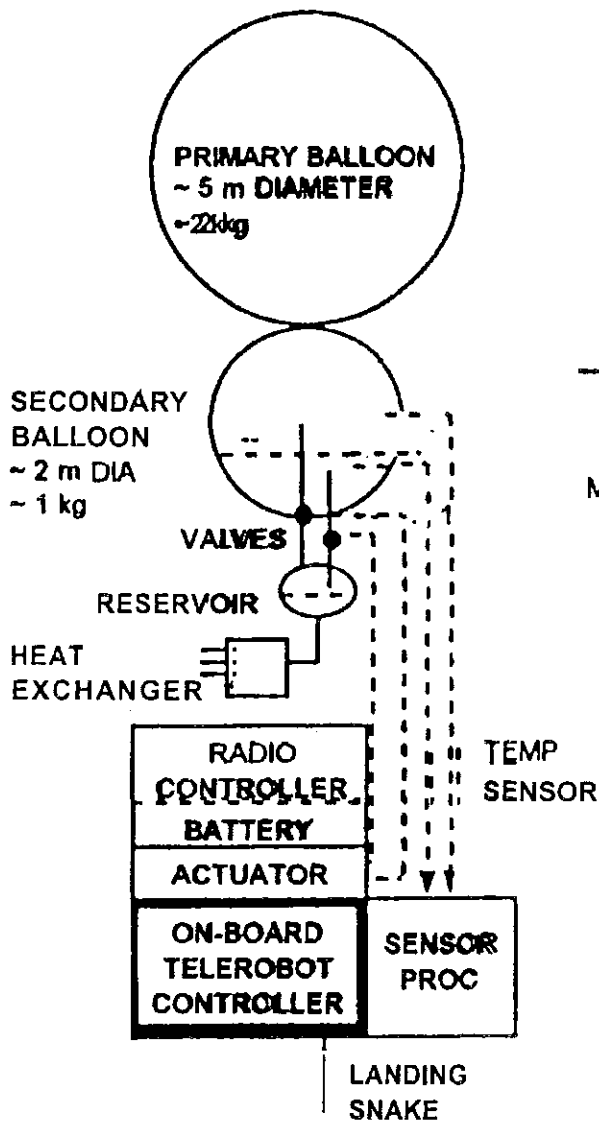


Stabilization at 2 km

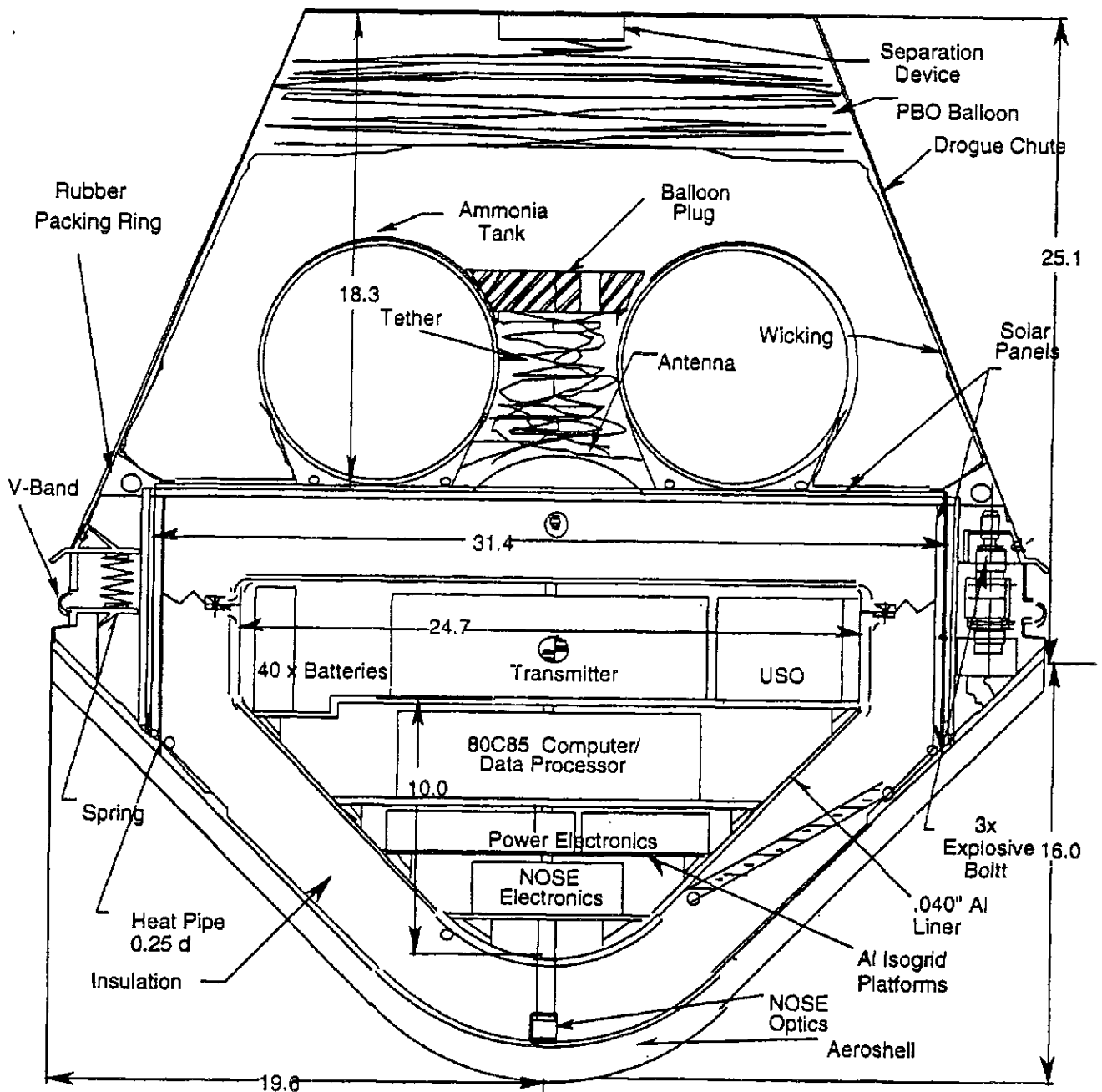


Aerobot Trajectories along an Atla Regio Geotraverse



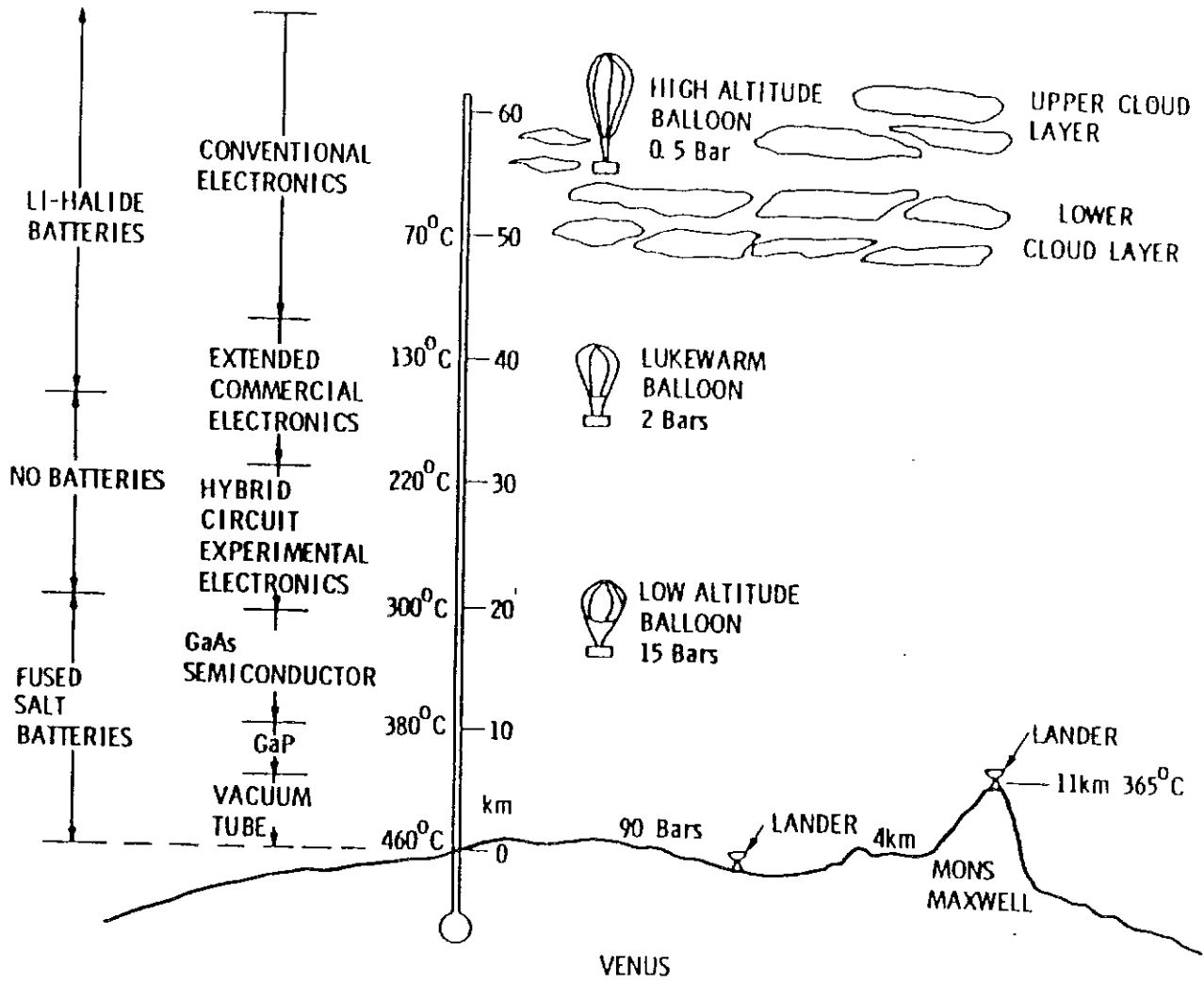


Planetary Aerobot Testbed Vehicle System



(All measurements in cm)

VENUS HIGH TEMPERATURE ELECTRONICS



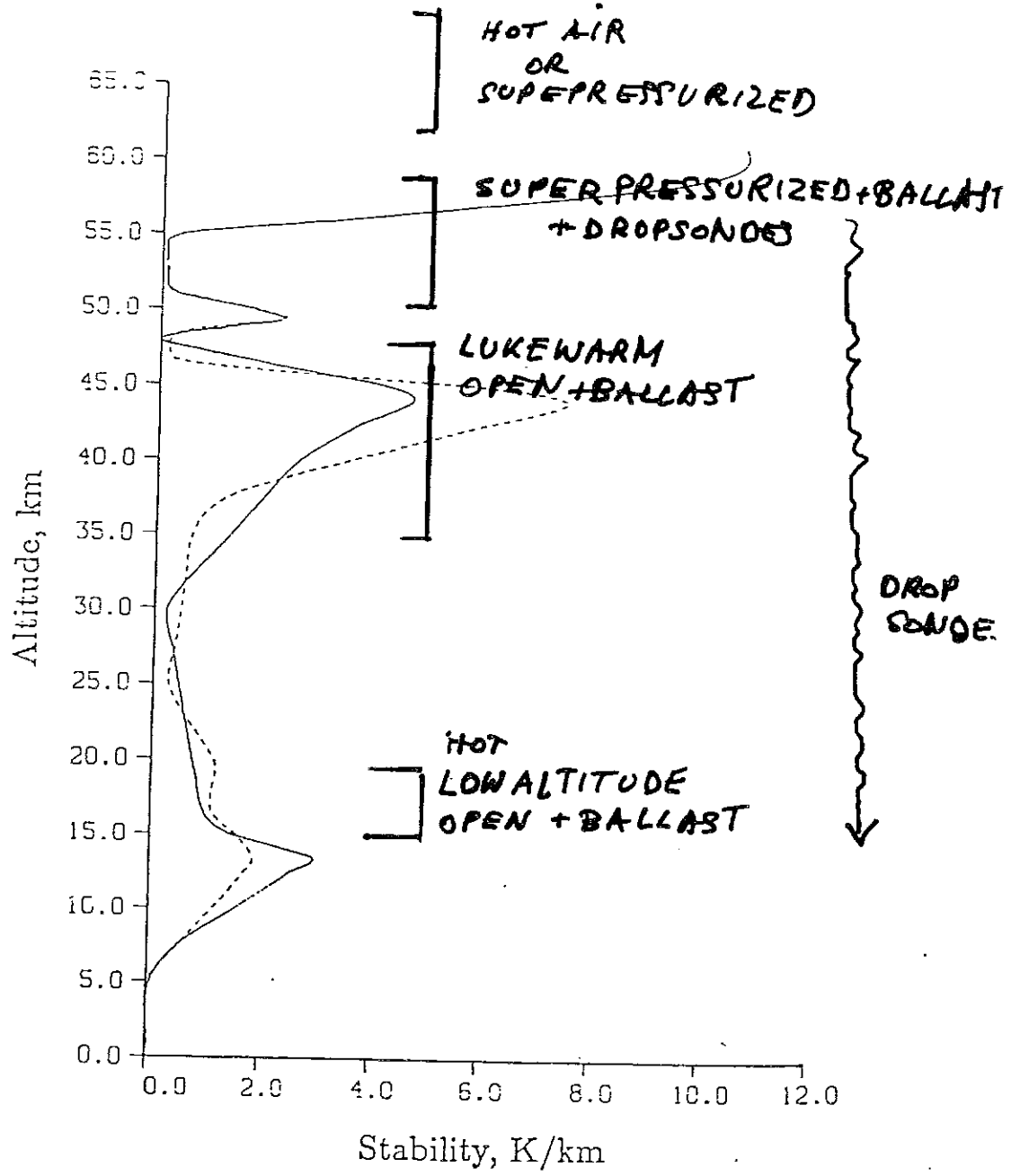


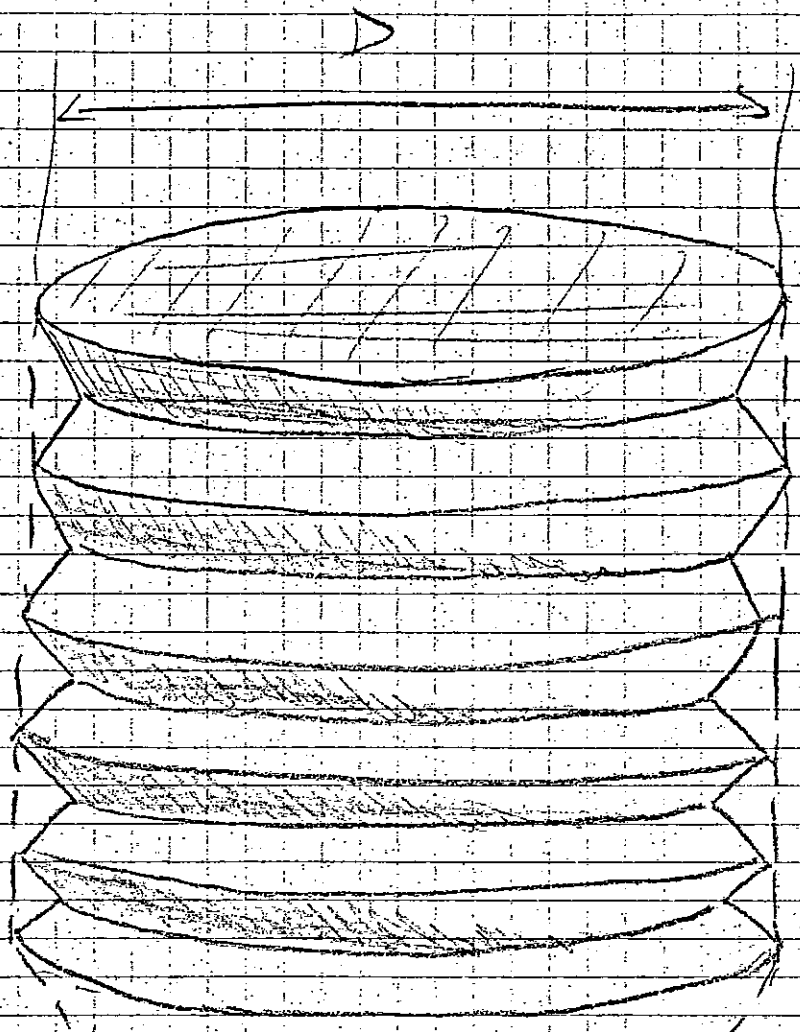
FIG 1(b)

VENUS HIGH TEMPERATURE BALLOON REQUIREMENTS:

1. MISSION DURATION	2 wks
2. GROUND BASED VLBI TRACKING	100 km ERROR
3. WEIGHT	≤ 2 kg
4. FREQUENCY	1000 TO 3000 MHz
5. EMISSION	PULSE OR CW
6. ANTENNA	CIR. POL. OMNI-DIR.
7. ALTITUDE	18 km
8. TEMPERATURE	300 ⁰ C TO 350 ⁰ C

SIBLE

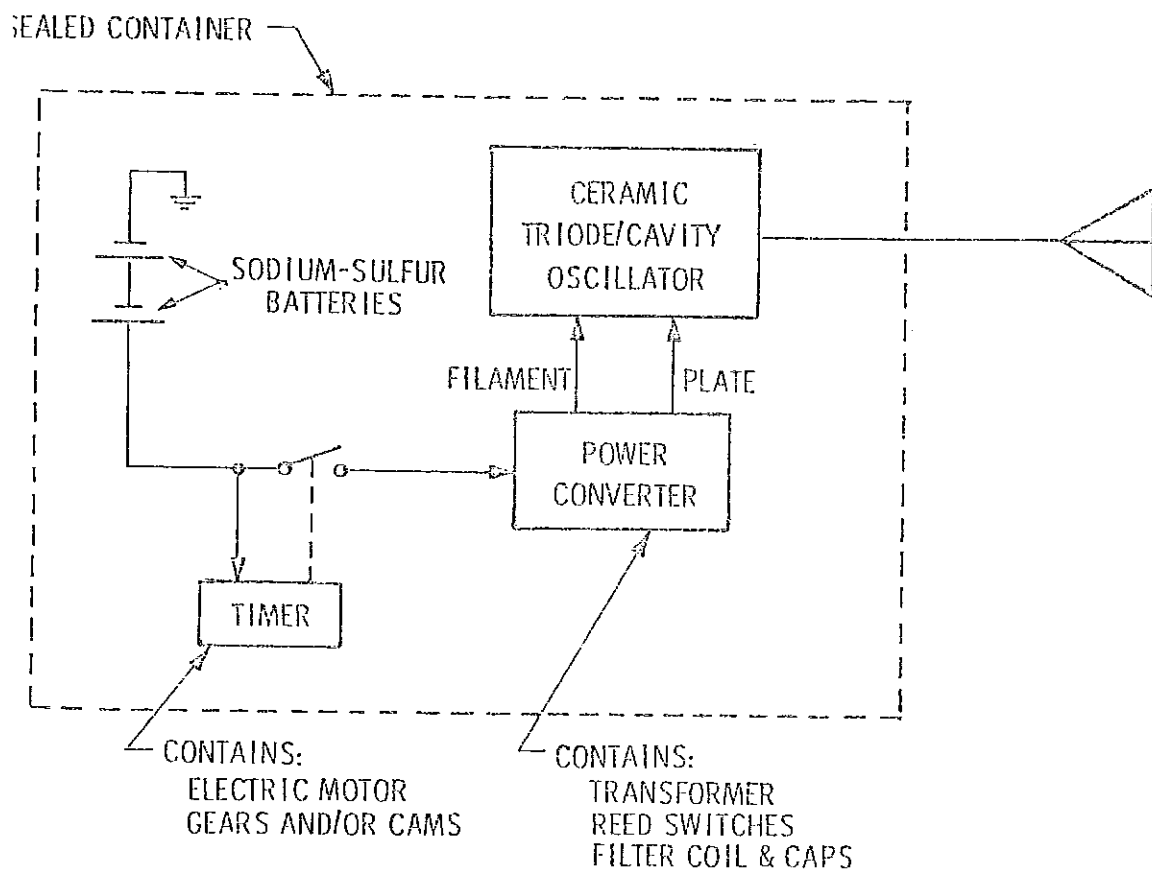
9. MEASURE TEMPERATURE	(POSSIBLE)
10. PRESSURE	(POSSIBLE)
11. LIGHT INTENSITY	(DIFFICULT)



réflect

Figure 2 Schéma du Campus

BEACON FOR LOW ALTITUDE VENUS BALLOON



LOW ALTITUDE

MISSION TRAJECTORY: UNKNOWN
INJECTION: NOT CONSTRAINED
ALTITUDE: 20 KM
PAYLOAD: 10 KG, NOT INCLUDING BALLAST

BALLOON TYPE: OPEN, STABILIZED BY BALLAST
FILLING GAS: H2O
PACKAGING TO BE DEVELOPED
DIAMETER: 2 M
VOLUME: 4 M³

MASS: 1.	FLOATING	GONDOLA	10
(KG)		BALLAST	20
		BALLOON	6
		H2O	23
		TOTAL	<u>59</u>
2.	JETTISONED	TANKS	10
		EXCHANGER	
		STRUCTURE	30
		TOTAL	<u>40</u>
3.	GRAND TOTAL		89

MEDIUM ALTITUDE (1) (CONSTANT LEVEL)

SION MORE THAN ONE COMPLETE REVOLUTION, NIGHT INJECTION
ALTITUDE FIXED AT 55 KM, CONSTANT LEVEL
PAYLOAD: (NOT INCLUDING BALLAST)
1 GONDOLA 30 KG
12 X 5KG DROPSONDES 90
120

LOON TYPE: SUPER PRESSURIZED, WITH VALVE AND BALLAST
FILLING GAS: HELIUM
DEVELOPED FOR VENERA 84
DIAMETER: 8 M
VOLUME: 250 M³
ΔP MAX 50 MBAR
MASS: 1. FLOATING GONDOLA 120
(KG) BALLAST 25
BALLOON 75
HELIUM 24
TOTAL 244
2. JETTISONED TANKS 300
STRUCTURE 150
3. GRAND TOTAL 700

MEDIUM ALTITUDE (2) VERTICAL EXCURSIONS

MISSION

- 1/2 CIRCUMNAVIGATION FROM MIDNIGHT TO NOON
- VERTICAL EXCURSIONS FROM 40 to 50 KM ALTITUDE
- ABOUT 10 TO 20 SUCH EXCURSIONS DURING MISSION
- MAXIMUM TEMPERATURE: 160°C.
- PAYLOAD 10 KG NOT INCLUDING BALLAST

BALLOON

TYPE: OPEN, STABILIZED BY BALLAST

FILLING GAS: HELIUM

NO DEVELOPMENT NEEDED

DIAMETER: 3.5 M

VOLUME: 20 M³

MASS: 1. FLOATING	GONDOLA	10
(KG)	BALLAST	12
	BALLOON	8
	HELIUM	3
	TOTAL	<u>33</u>
2. JETTISONED	TANKS	42
	STRUCTURE	20
		<u>62</u>
3. GRAND TOTAL		95

HIGH ALTITUDE (65 - 70 KM)

MISSION MORE THAN ONE CIRCUMNAVIGATION
NIGHT INJECTION
VERTICAL EXCURSIONS (2 to 3 KM)
PAYLOAD: 30 KG NOT INCLUDING BALLAST

BALLOON TYPE: OPEN, STABILIZED BY BALLAST
FILLING GAS: HELIUM
NO DEVELOPMENT NEEDED
DIAMETER: 10 - 15 METER
VOLUME: 500 TO 1700 M³
MASS: 1. FLOATING CONDOLA 30
(KG) BALLAST 25
BALLOON 30 TO 75
HELIUM 9 TO 14
TOTAL 96 TO 134
2. JETTISONED TANKS 115 TO 175
STRUCTURE 70 TO 100
AND DEPLOY
TOTAL 155 TO 275
3. GRAND TOTAL 280 TO 410

HIGH ALTITUDE (Z>65 KM)

(2) SOLAR GAS BALLOON

MISSION DAY ONLY, INJECTION NEAR SUBSOLAR POINT
ALTITUDE 64 - 66 KM
PAYLOAD 30 KG

BALLOON TYPE: OPEN, STABILIZED BY BALLAST
FILLING GAS: CO₂
NO DEVELOPMENT NEEDED

DIAMETER: 12 M

VOLUME: 1000 M³

MASS: 1. FLOATING	CONDOLA	30
(KG)	BALLOON	90
	TOTAL	<u>120</u>
2. JETTISONED	STRUCTURE	60
	AND DEPLOY	<u>60</u>
3. GRAND TOTAL		180

HIGH ALTITUDE (Z > 65 KM)

(3) LIGHT GAS BALLOON

MISSION 1/2 CIRCUMNAVIGATION FROM MIDNIGHT TO NOON
ALTITUDE: 65 KM
PAYLOAD: 5 KG

BALLOON TYPE: OPEN, THERMALLY STABILIZED
FILLING GAS: CO₂
DEVELOPMENT NEEDED
DIAMETER: 15 M
VOLUME: 4000 M³

MASS:	1.	FLOATING	BALLOON	35
(KG)			TOTAL	<u>35</u>
	2.	JETTISONED	STRUCTURE	<u>40</u>
	3.	GRAND TOTAL		75

A Mission Concept for

Venus Sample Return

June 27, 1985

Dr. Jacques Blamont

Ross Jones

Dr. Angus McDonald

Carl Sauer

Chris Purvis

- Due to the long Series of Successful Missions to Venus (Mariner 2 & 5 & 10, Venera 1-12, Pioneer Venus, VEGA 1 & 2) and the Approved VRM Project and the Interest In Sample Return from Mars and Comets IT IS TIME TO CONSIDER A VENUS SAMPLE RETURN MISSION
- The Mission Objective is to Return at least one 1kg sample of the Venus Surface to Earth Orbit
- Mission Concept Proposed by Dr. Blamont includes Balloons and Airplanes in the VENUS Atmosphere
- The Venus Sample Return Mission is similar in size and challenge to the Mars Sample Return Mission

Mission Mode Options

- Direct Return from surface
- *Ascent Vehicle carried to surface and ignited at mid-altitude
- **Balloons with airplane transfer and mid-altitude ignition of Ascent Vehicle
- Tethers dragged along surface from mid altitude balloon or kite



Trajectory Options*

<u>Opportunity</u>	<u>Earth Departure Date</u>	<u>Deep Space ΔV Date</u>	<u>Earth to Venus Time</u>	<u>Venus Arrival Date</u>	<u>Venus Stay Time</u>	<u>Venus Departure Date</u>	<u>Venus to Earth Time</u>	<u>Earth Arrival Date</u>
1999	6/9/99	-	140 days	10/24/99	461	1/30/01	129	6/8/01
1996 Direct	4/8/96	-	110	7/27/96	493	12/3/97	183	6/4/98
1996 Broken Plane	3/6/96	3/28/96	152	5/28/96	485	12/3/97	183	6/4/98

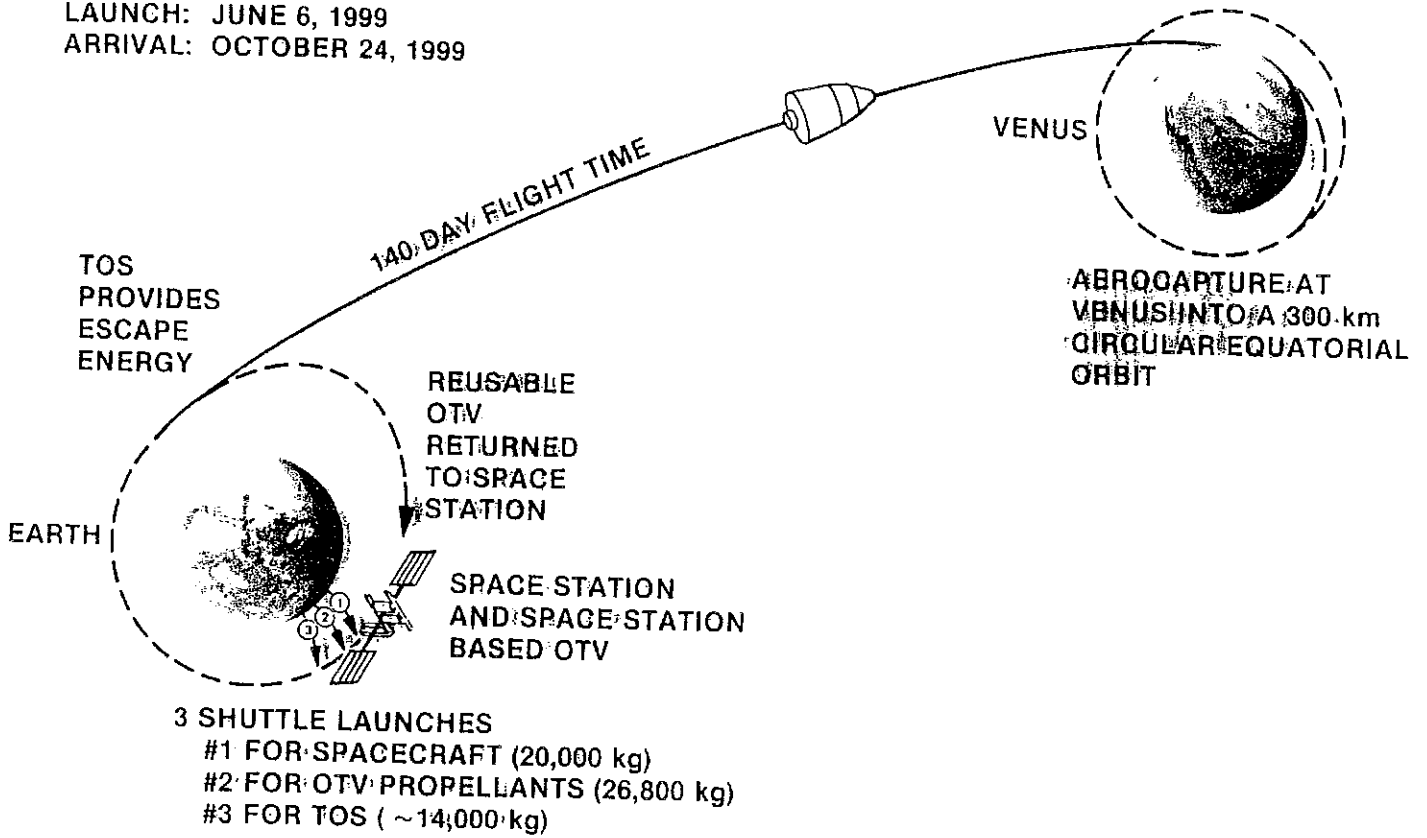
	<u>Earth Departure C_3</u>	<u>Deep Space ΔV</u>	<u>Venus Arrival ΔV</u>	<u>Venus Departure ΔV</u>	<u>Earth Arrival V_0</u>
1999	9.3 km ² /s ²	-	3.39 km/s	3.67 km/s	3.32 km/s
1996 Direct	17.6	-	5.1	3.43	4.05
1996 Broken Plane	5.67	1.87	3.32	3.40	4.05

*Final Venus Orbit: 300 km circular equatorial



VENUS SAMPLE RETURN PHASE I

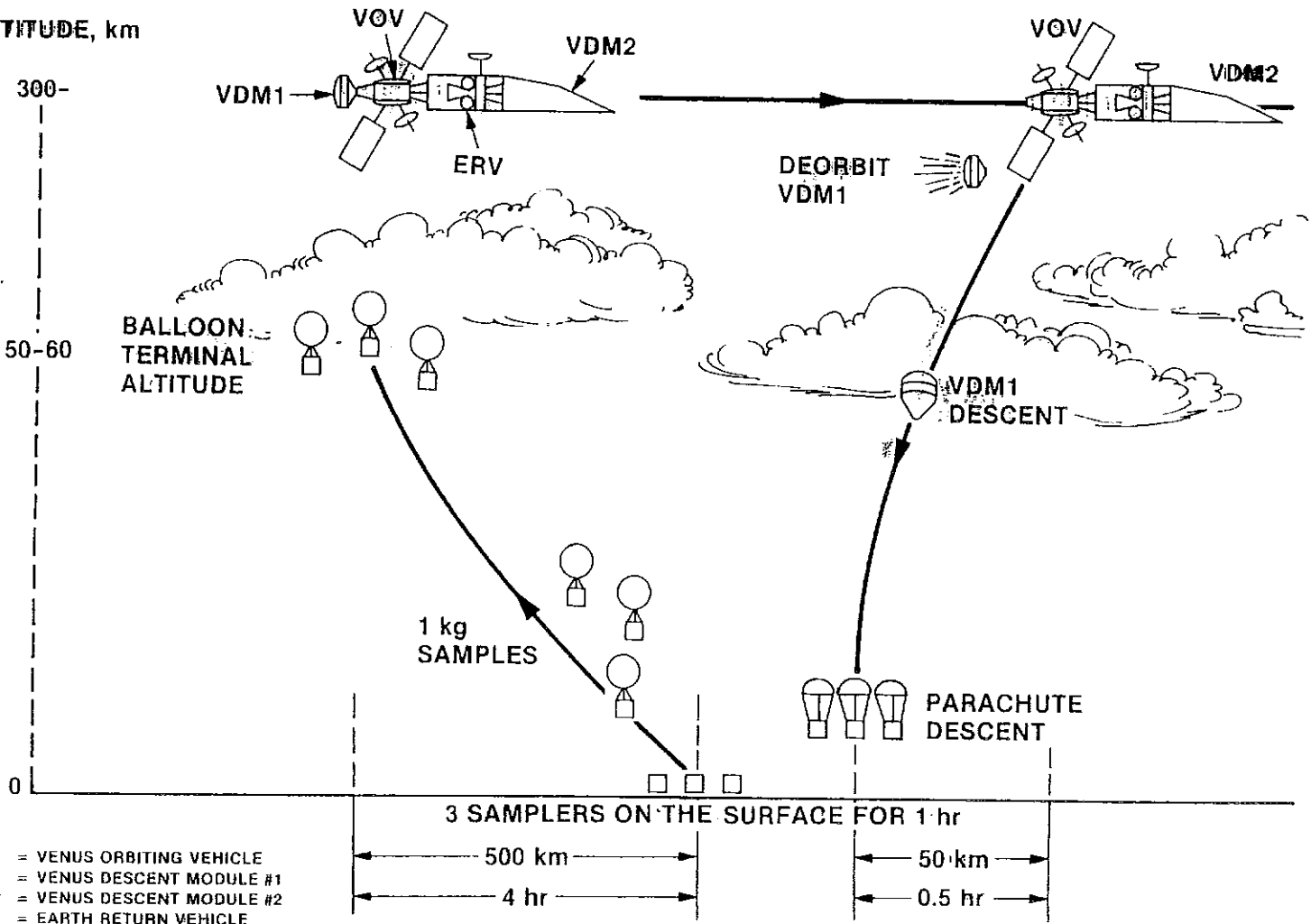
LAUNCH: JUNE 6, 1999
ARRIVAL: OCTOBER 24, 1999





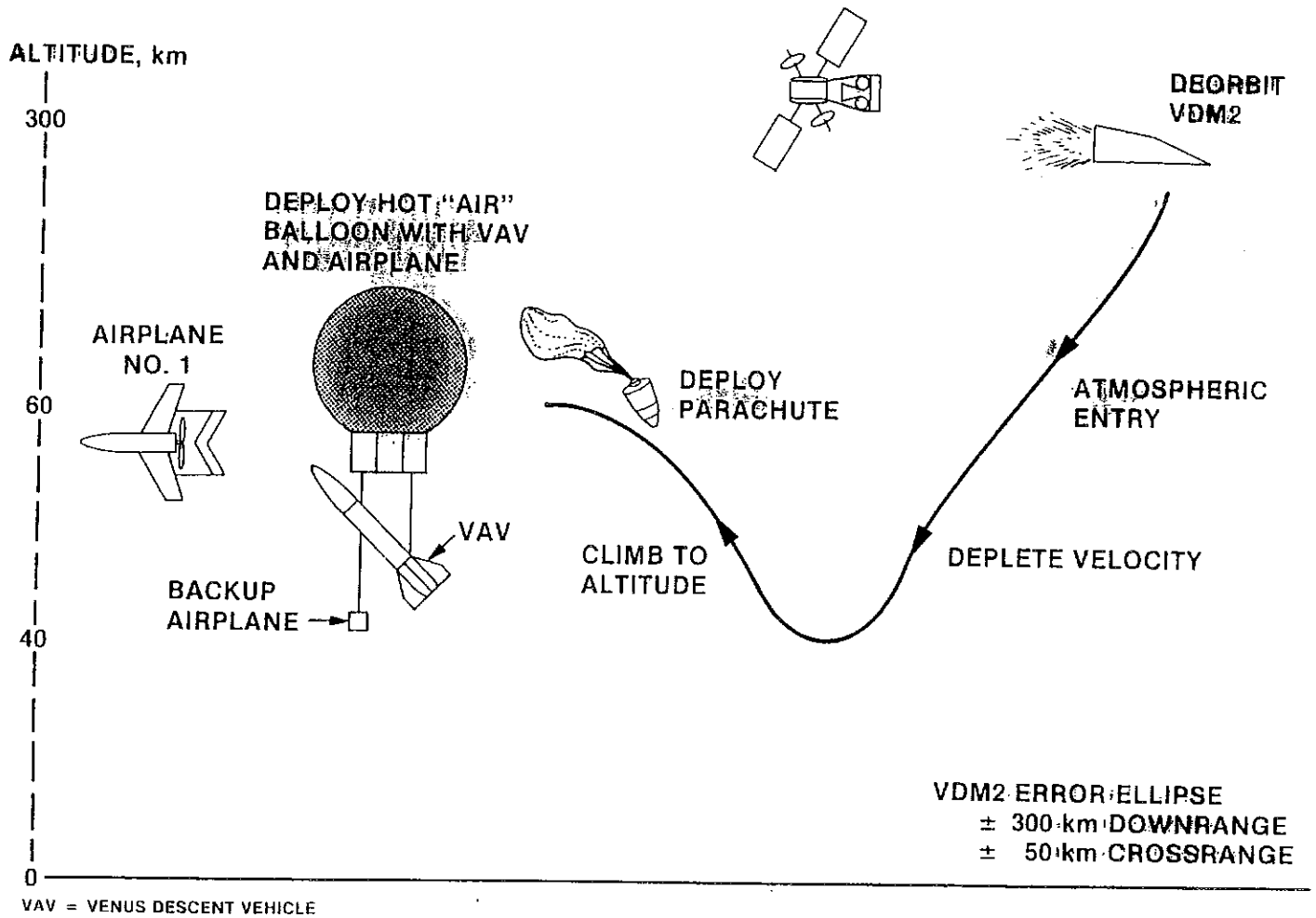
VENUS SAMPLE RETURN PHASE II

ALTITUDE, km



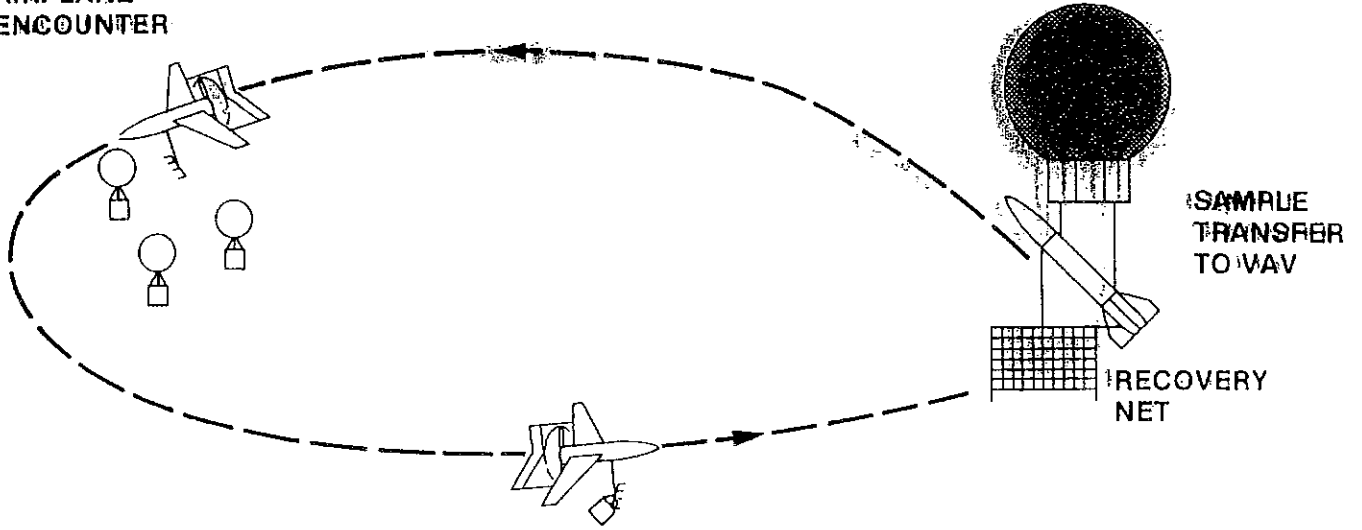


VENUS SAMPLE RETURN PHASE III



VENUS SAMPLE RETURN PHASE IV

BALLOON
AIRPLANE
ENCOUNTER





VENUS SAMPLE RETURN PHASE V

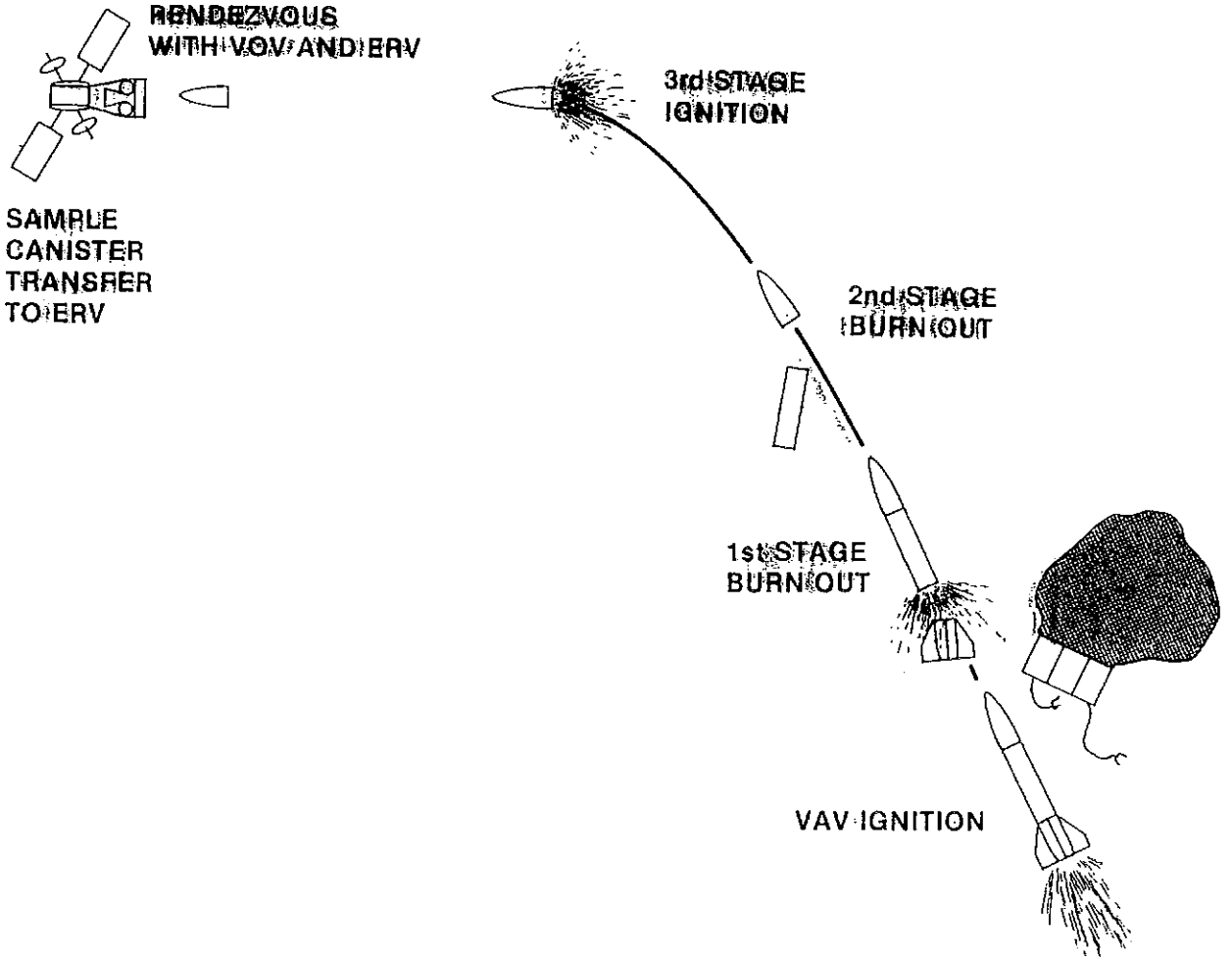
ALTITUDE, km

300

150

80

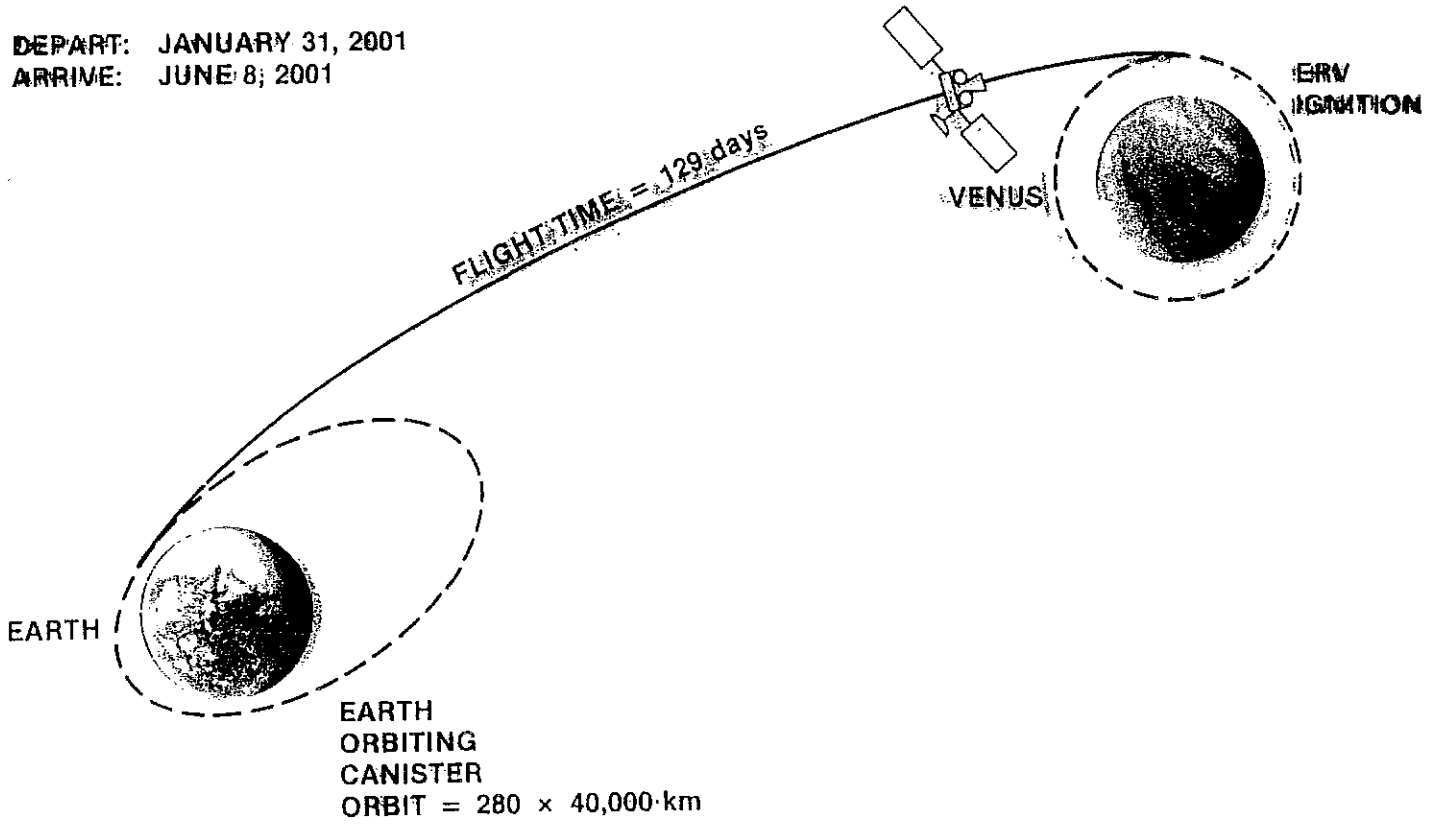
60





VENUS SAMPLE RETURN PHASE VI

DEPART: JANUARY 31, 2001
ARRIVE: JUNE 8, 2001





Venus Sample Return Comparison to Mars Sample Return

	<u>MSR (JPL-D-1345)</u>	<u>VSR</u>
● Sample Mass	5kg	3
● Shuttle Launches	2	3
● Injected Mass	9489kg	20,000
● Upper Stage	Centaur G	Reuseable 4 Tank OTV+ TOS
● Mission Length	2.8yr	2.0
● Mission Elements	Earth Orbiting Canister	Earth Orbiting Canister
	Earth Return Vehicle	Earth Return Vehicle
	Mars Orbiting Vehicle	Venus Orbiting Vehicle
	Mars Ascent Vehicle	Venus Ascent Vehicle
	Mars Landing Module	Venus Descent Module #1
	Mars Entry Capsule	Venus Descent Module #2
	Mars Rover	Venus Airplane
		Venus Balloons



Summary and Conclusions

- Sample Return from Venus is supported by a large number of previous missions to Venus and by COMPLEX documents.
- Based upon Preliminary Work, Mission Concept Appears Feasible
- Mission Concept is similar to Mars Sample Return in shuttle launches, complexity, Time and presumably cost
- Venus Sample Return does not require, but is a good candidate for International (NASA, ESA, CNES, IKI) cooperation
- The current Mission Concept is complex and requires technologies new to planetary missions, i.e. aerocapture, airplanes, and hot air balloons. However all the required technologies are supported by terrestrial equivalents and the majority of the new technologies could be tested on Earth.
- This mission concept avoids putting complex, high technology vehicles into the hostile Venus surface environment.
- MSR and VSR could be parts of a common sample return program since they have many common features and elements.