Tool for Planetary Probe Payload Sensor System Integration

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OBJECTIVES

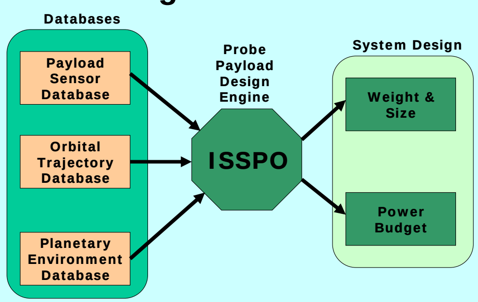
Determination of instrumentation for interplanetary science mission is an involved, complex procedure. A final design solution is achieved at the end of this often lengthy process. Starting with mission requirements a computer program generates a mission sensor package using design engineering relations. Given broad science goals for an interplanetary science mission, the specific scientific measurement objectives required can be determined from which the required measurements flow down, leading to an overall mission design. The mission design drives the instrumentation requirements and influences the selection of components for the mission. Components are chosen to meet mission requirements, creating an initial sensor package design. Trade studies are performed at component levels. A tool for in-situ measurements is developed using design relations to deliver a sensor payload configuration starting from the initial mission concept and the specific measurement objectives.

Introduction

Interest in developing this program came from the short course on In-Situ Instruments for Planetary Probes and Aerial Platforms at the 4th International Planetary Probe Workshop.

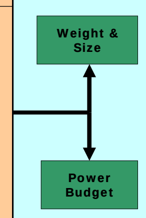
- Given mass and power budget for a planetary probe mission.
- Develop a sensor package meeting the science requirements and fit within the mission constraints. Sensors are chosen to survive the operating environment and mission requirements.
- Design of the sensor payload package for any mission addresses arises from several issues:
  - Functionality
  - Heritage
  - Technology Readiness Level (TRL)
  - etc.
- Combination of selection techniques for mission hardware, allows the development of a tool that can generate a preliminary sensor package configuration.

Program Process



System Architecture Design

Payload Sensors	Sensor Specifications	Planetary Environment
AC Field	N/A	Planet Properties
Accelerometer	Acc Level / Power Type	
Acoustic	Sensor Type	
GCMS	Sensor Type / Range	
Imaging	Type / Res / Spectrum	
Inclination	Inclination level	
Nephelometer	N/A	
Radiation	Radiation Type	
Refraction	N/A	
Digital Sig. Processing	Processor Speed / Number of Devices	
Atmosphere	N/A	
Temperature	Sensor Type	
Pressure	N/A	
Humidity	N/A	
Wind Velocity	Sensor Type	
Density	Sensor Type	

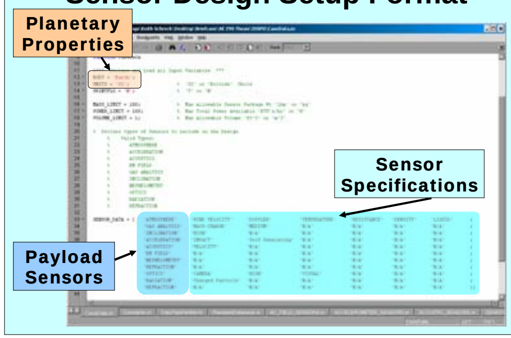


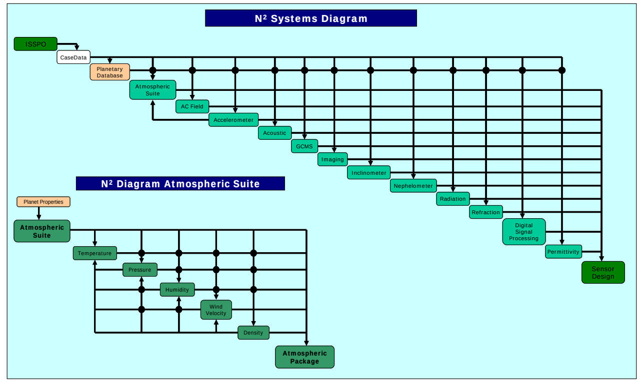
Huygens Probe

Sensor Design Tool Tested against Huygens Probe Sensor Packages including:

- •Descent Imager Spectral Radiometer (DISR)
- •Doppler Wind Experiment (DWE)
- •Gas Chromatograph Mass Spectrometer (GCMS)
- •Huygens Atmospheric Structure Instrument (HASI)
- •Surface Science Package (SSP)

Sensor Design Setup Format





Sensor Tool Operation

Based on a Planetary Body and the type of sens
data to be returned from the planetary mission
(sensor types) a package of commercially availal
sensor components is determined.

Summary Data file written with sensor Mass, Pov
and Volume requirements. Detailed sensor files
generated containing sensor specific properties a
characteristics.

Surface Science Package (SSP)

Atmospheric Sensor components mixture of commer
the shelf hardware and custom designed sensor elen

Surface Science Package (SSP) Scientific Objectives
Determine the physical nature and condition of Titan's surface at the landi
Determine the abundances of the major constituents, placing bounds o atmospheric and ocean evolution
Measure the thermal, optical, acoustic and electrical properties and densi any ocean, providing data to validate physical and chemical models
Determine wave properties and ocean/atmosphere interaction
Provide ground truth for interpreting the large-scale Orbiter Radar Mappe other experimental data

SSP Sensor Components		
Sensor	Flight Unit	ISSPO Results
Accelerometer – Impact penetrometer ACC-E	Piezoelectric Ceramic PZT-5A	N/A Custom Design
Accelerometer - Impact accelerometer ACC-I	Endevco 2271AM20 0 – 100 g's	Endevco 2271AM2
Tilt Sensor TIL	Spectron L-211U +/- 60°	Spectron L-211U
Temperature Sensor THP	Hot Wire 65 – 100 K	M-0146MD
Velocity of Sound API-V	Piezoelectric Transducers – 2 150 – 2000 m/s	Physical Acoustics R30 A
Acoustic Sounder API-S	Piezoelectric Transducers Array	N/A
Fluid Permittivity PER	Capacitance Sensor	N/A Custom Design
Density of Fluid DEN	Archimedes Sensor 400 – 700 kg/m3	N/A Custom Design
Refractive Index REF	Critical Angle Refractometer 1.25 – 1.45	Huygens Design

Custom configurations for permittivity sensor, densito
acoustic sounder array components.

IMPACT

Development of this tool allows the exploration of different sensor technological capabilities, and the ability to integrate the individual sensors into a cohesive package. Data on the resulting sensor package, drives the design of the probe' support systems (power, size, & shape) for a given planetary mission.

Huygens Atmospheric Structures Instrument (HASI)

Atmospheric Structure Sensor Package components mixture of commercial of the shelf hardware and custom designed sensor elements.

HASI Sensor Packages		
Sensor Package	Sensor Type	Measured Parameter
Accelerometers (ACC)	3-Axis Acc	Atmospheric deceleration, Descent Monitoring, Impact Response
Pressure Profile Instrument (PPI)	Kiel probe, capacitive gauges	Atmospheric Pressure
Temperature Sensor	2-Dual Element Platinum Thermometers	Atmospheric Temperature
Permittivity, Wave & Altimetry (PWA)	Mutual impedance	Atmospheric electric conductivity
	AC field measurement	Wave electric fields & Lightning
	Relaxation probe	Ion conductivity and DC electric field
	Acoustic sensor	Acoustic noise due to turbulence of storms
	Radar signal processing (FFT)	Radar echoes below 60 km altitude

HASI Sensor Package Components		
Sensor Package	Flight Unit	ISSPO Sys Architecture
Accelerometer – 3 axis servo	Sundstrand QA-2000-030	Sundstrand QA2000-030
Accelerometer - piezo-resistive	Endevco 7264A-2000T	Endevco 7264A-2000T
Pressure Profile Instrument	Vaisala - Barocap	Series 48-0025
Temperature Sensor	dual element platinum resistance thermometers Rosemount Aerospace Inc	Goodrich Model 0146MD
PWA – Acoustic Sensor	Kulite CT-190M	Kulite CT-190M
PWA – Digital Signal Processor(FFT)	Analog Devices ADSP-2100A	Analog Devices ADSP-2100A

Venus Atmosphere Mission

Mission Concept

•Cloud Level Atmosphere (~70 km) appears to rotate as a solid body with a period of 4 da approx 60x faster than the surface. The mechanism driving the super-rotation is currently unknown.

Sensor Components

Venus Atmospheric Mission Objectives	
Mission Data	Objective Reasoning
ATMOSPHERE - Temperature	Provide Atmospheric Temperature consistent with mission trajectory, provides temperature calibration data for other sensors onboard
ATMOSPHERE - Pressure	Provide Atmospheric Pressure consistent with mission trajectory, provides pressure calibration data for other sensors onboard
ATMOSPHERE – Wind Velocities	Measure Wind Velocity profiles throughout the atmospheric descent, providing data to validate physical models
INCLINATION	Provides spacecraft orientation information to determine relative wind flows around spacecraft
ACCELERATION	Provide descent deceleration profile information and use for event sequence timings
EM FIELD	Map planetary magnetic field to determine if it accounts for observed wind flows
RADIATION	Detect charged particle occurrences in the atmosphere looking for energetic reactions in the atmosphere
OPTICS	Provide in-situ visual observations of wind flows in visual, ultraviolet, and infrared wavelengths to track cloud motion patterns

Sensor Package Components

ISSPO Venus Atmosphere Sensor System Architecture Results						
SENSOR	NAME	RANGE	MASS	VOLUME	POWER	Comme
ATMOSPHERE – Temperature	K	-200 – 1250 deg C	0	0	0	Based on Planetary Type
ATMOSPHERE – Pressure	13(C,U)2000P	0 – 13789.5 kPa	0	29.41 cm³	0.030 W	Based on Planet
ATMOSPHERE – Wind Velocities	FT 702	0 – 70 m/s	0.300 kg	0.0004 m³	0	Based on Range, M Accura
INCLINATION	L-212T	-45 – 45 deg	0	12.00 cm³	0	Based on Tilt
ACCELERATION	MA13	-30 - 30 g's	0.1417 kg	47.72 cm³	0.64 W	Acceleration Range
EM FIELD	TAM-1	0 – 1000 mG	1.000 kg	0.0016 m³	0	Based on Planet
RADIATION	LPD	0 – 250 MeV	7.00	0.0067 m³	15 W	Radiation Type
OPTICS	CCD 3041	UV VISUAL NIR	0	3.304 cm³	0	Imaging Type, R Spectrum, Full w
SUMMARY			8.7217 kg	0.00871 m³	15.77 W	

Descent Imager Spectral Radiometer

Flight Unit is a modified version of Commercially available unit

Sensor Type	Fairchild Imaging CCD 424
Imaging Spectrum:	X-RAY UV VISUAL NIR
Array Dimensions - Length:	1024 # Pixels
Width:	1024 # Pixels
Sensor Pixel Size:	21.0000 micro-m
Imaging Array Size - Length:	21.500 mm
Width:	21.500 mm
Dimensions - Length:	73.15 mm
Width:	52.83 mm
Height:	6.10 mm

Unit with similar capabilities, image binning technology determined.

Doppler Wind Experiment

Combination of commercial hardware and university research. Commercial Unit with similar operational properties selected by tool.

Doppler Wind Experiment Properties				
Scientific Objectives:				
Determine the height profile of Titan zonal wind velocity over the altitude range from 0 – 160 km with an accuracy of ~1 m/s				
Measure Doppler fluctuations to determine the level and spectral index of turbulence and possible wave activity in Titan's atmosphere				
Measure Doppler and signal level modulation to monitor Probe Descent Dynamics, including its rotation rate and phase, parachute swing and post-impact status				
Physical Properties:	Flight Unit Properties		Symmetricom 8130A	
Mass (g)	1191	radiation shielding: 150 g	900	
Dimensions (mm)	170 × 117 × 119	L × W × H	102.6 × 74.1 × 72.0	L × W × H
DC power:				
Warm-up power (W)	< 13.4	< 30 min	<35.0	< 10 min
DC consumption (mA)	< 675	System limit: 0.7 A	1094	At 12 V DC input
Energy (Wh)		worst case (minimum temp)		worst case (minimum temp)
Frequency Parameters:				
Output frequency (MHz)	10	± 0.1 Hz	10	
Frequency long term drift	1.4 × 10⁻⁹	δf₀/f₀ over 3 hours	<5.0 × 10⁻¹¹	After 1 month
Allan Variation	3 × 10⁻¹¹	τ = 1 s	3 × 10⁻¹⁰	τ = 1 s
	6 × 10⁻¹²	τ = 10 s	3 × 10⁻¹¹	τ = 10 s

Gas Chromatograph Mass Spectrometer

Multiple commercial hardware components assembled into Flight Unit Model. Selection based on sensing range of components within sensor tool database.

ISSPO GCMS Sensor Package Results		
Model : GCMS - Huygens		
Physical Properties:		
Mass (kg)	17.30	
Dimensions (mm)	470 × 192 × 198	L × W × H
DC power:		
Typical Power (W)	28	After 36 min warm-up period
Average Power (W)	41	At 28 V DC input
Peak Power (W)	71	
Sensing Parameters:		
Mass – Charge Range	2-141	amu
Number of Ion Sources	5	units
Ion Source Charge Field Range	1.00	W degas
	16.00	W degas