ROTARY WING DECELERATOR USE ON TITAN

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Motivation

- NASA Ames Academy

- Navigation research for TALARIS Project

TALARIS
Terrestrial Artificial Lunar And Reduced Gravity Simulator
MIT Space Systems Lab & Charles Stark Draper Laboratory

- Desire for controllable landing system for Titan

Image: Huygens Descent (ESA/NASA/JPL)

Atmospheric Deceleration on Titan

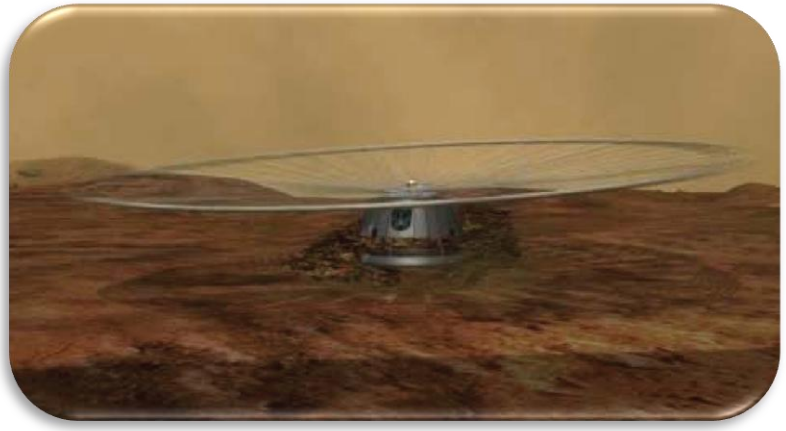
- Requirements:
  - Heading Control
  - Soft Landing
  - Power Generation
  - Atmospheric Research

Concept	Parachute (Baseline)	None	Drag Surfaces	Controllable Parachute	Retro Thrusters	Rotary Wing Decelerator
Cost	0	+	+	–	–	–
Weight	0	+	+	–	–	–
Controllability	0	0	0	+	+	+
Landing Speed	0	–	–	0	+	+
Power Gen.	0	–	–	0	0	+
Atm. Research	0	–	–	0	0	+
Total	0	-1	-1	-1	0	+2

Rotary Wing Decelerators

- Autorotating wings slow landing craft
  - Used for emergency landings in helicopters
- Accurate control
  - Terrain avoidance
- Low velocity touch down
  - "Soft-Flare" maneuver
- High-speed deployment tested up to Mach 3
  - Kaman Rotochute (1960s)

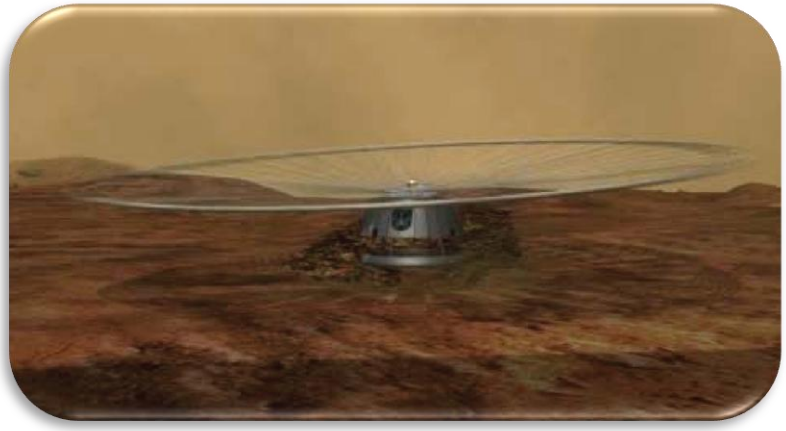
Venus: Young, et al/NASA Ames – IPPW-2



Mars: EADS Astrium/ESA - 2009

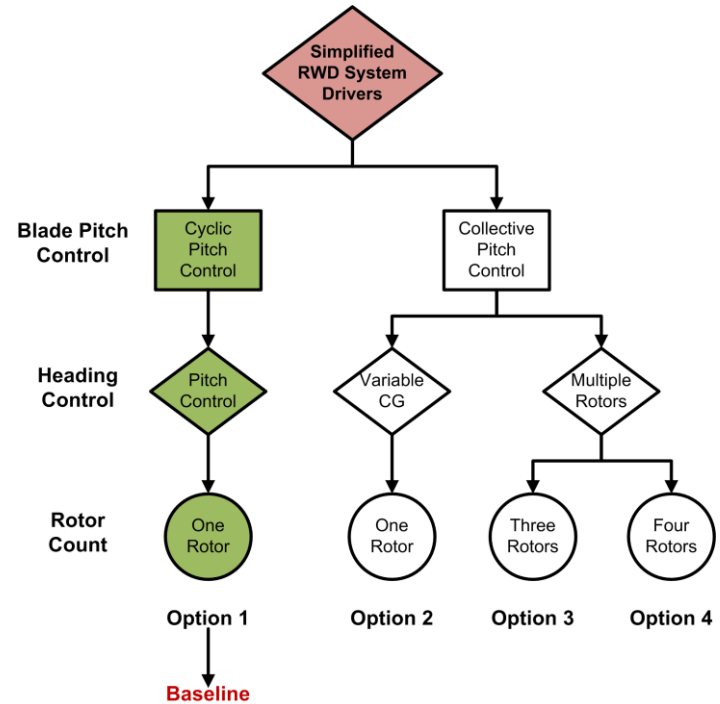
RWD Landing Sequence

1. Atmospheric entry
2. Rotor cover release
3. Rotor deployment
4. Rotor autorotation and probe deceleration
5. Heat shield release
6. Probe forward glide phase
7. Cyclic flare maneuver
8. Probe touchdown



RWD System for Titan

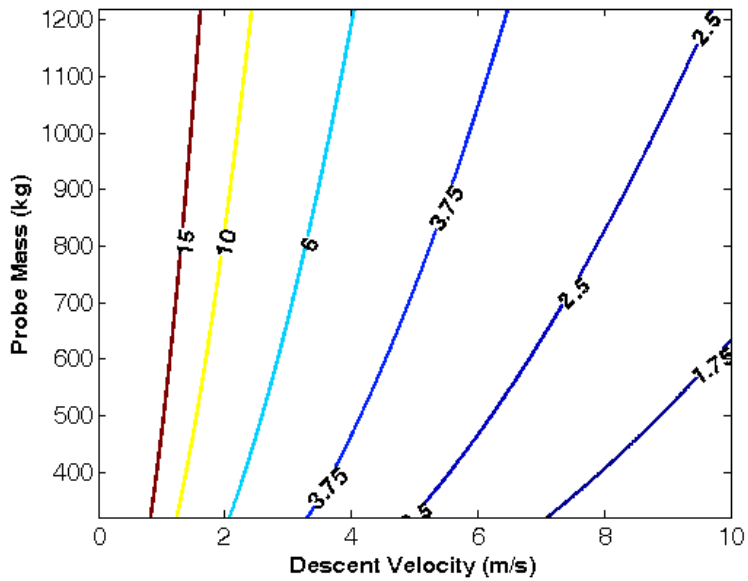
- System Drivers
  - Rotor Count
  - Blade Pitch Control
  - Heading Control
- Evaluation Criteria
  - Controllability
  - Complexity
  - Power Generation



Concept	Option 1 (Baseline)	Option 2	Option 3	Option 4
Heading Control	0	–	–	0
Descent Rate Control	0	0	0	0
Mech. Complexity	0	–	0	0
Power Generation	0	0	–	–
Total	0	-2	-2	-1

RWD System Design

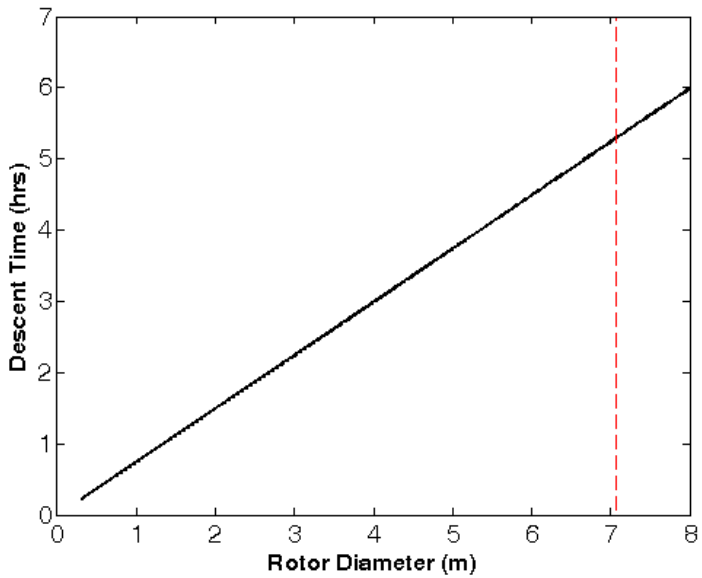
Rotor Diameter



$$d = \frac{1}{V}\sqrt{\frac{8mg}{\pi\rho C_D}}$$

ρ=5.25 kg/m^3
g=1.345 m/s^2
C_D=1.23

Descent Time

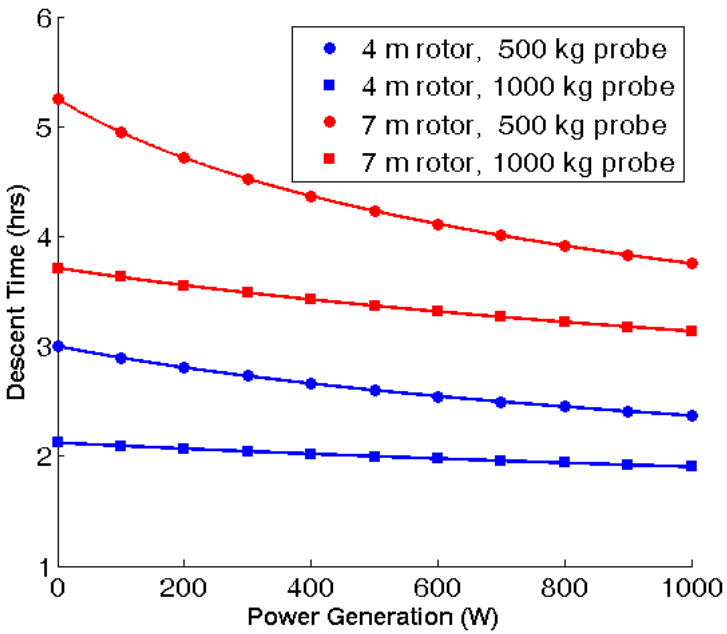


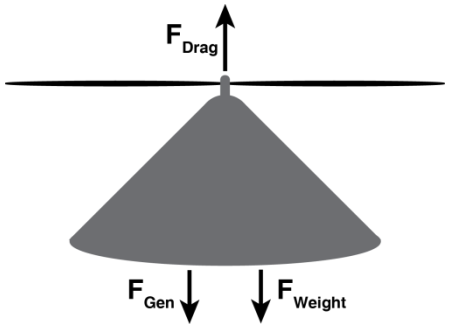
$$t_{descent} = \frac{hd}{\sqrt{\frac{8mg}{\pi\rho C_D}}}$$

h= 42 km
m=500 kg

Power Generation

- Navigation sensors are power demanding
- Power can be extracted from spinning rotor
- Power extraction decreases descent time





$$P = \eta V(\frac{1}{8}\pi\rho d^2 C_D V^2 + mg)$$

$$\eta = 0.5$$

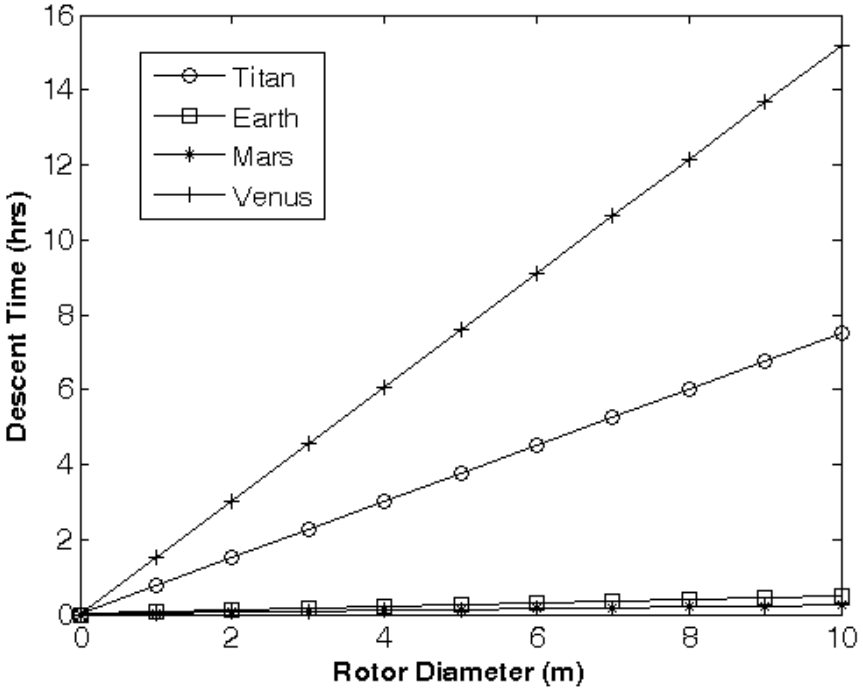
Summary

- RWD systems can provide controllable landing on Titan
- Trade space evaluation results in single rotor utilizing cyclic pitch control
- Rotor sizing for acceptable descent on Titan allows simplified deployment
- Power extraction can be variably traded against descent time in RWD systems

Backup Slides

Applications to Other Planets

Planet	Atmospheric Density (kg/m^3)	Tropospheric Extent (km)	g (m/s^2)
Titan	5.75	42	1.345
Earth	1.20	17	9.80
Mars	0.02	40	3.71
Venus	65	65	8.87



Model Assumptions

- Constant atmospheric density
- Constant drag coefficient (autorotative)
- Generator efficiency (50%)
- Purely vertical descent
- Small probe diameter