
FORCE

FORCE = MASS X ACCELERATION

FORCE

WHY DO ASTRONOMERS CARE ABOUT

FORCES?



Landing system of the Curiosity™ Mars Rover

In order to land the Mars rover, NASA developed a new, never-before used technology known as the “Sky Crane”

10 minutes to touchdown:

the capsule carrying Curiosity separates from its cruise stage and enters Mars' atmosphere at 13,200 mph (21,240 kph).

Parachute Deploy

10:15:05 PM PDT
10:28:53 PM PDT

Entry Interface

10:10:46 PM PDT
10:24:34 PM PDT

The parachute deploys

at an altitude of 7 miles (11 km) and the heat shield falls away. At this point speed is about 900 mph (1450 kph).

Heatshield Separation

10:15:25 PM PDT
10:29:13 PM PDT

As it nears the surface, retro rockets fire to slow the vehicle to 1.7 mph (2.75 kph). The “sky crane” is deployed to lower the Curiosity gently to the Martian surface.

Touchdown

10:17:57 PM PDT
10:31:45 PM PDT

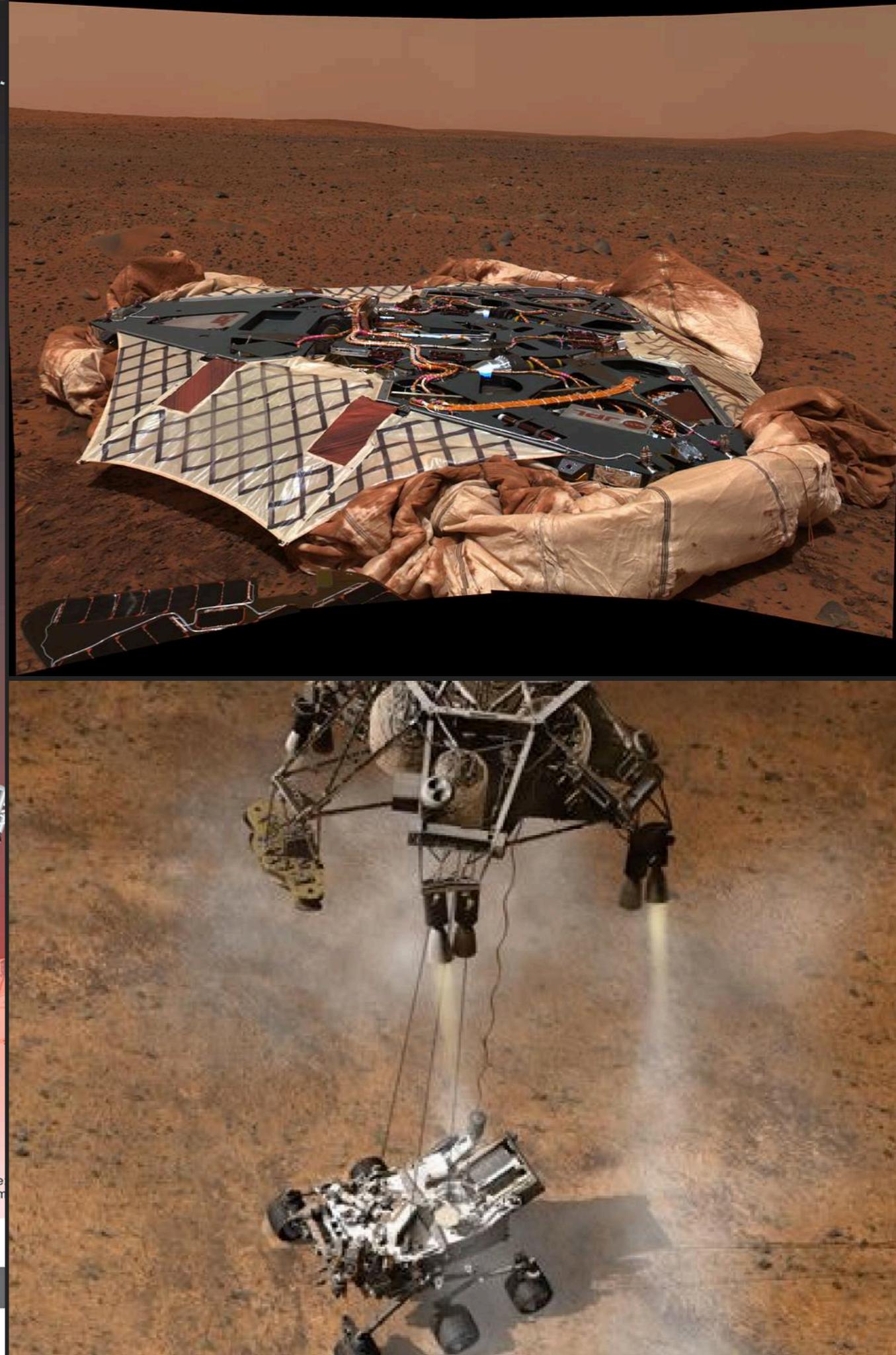


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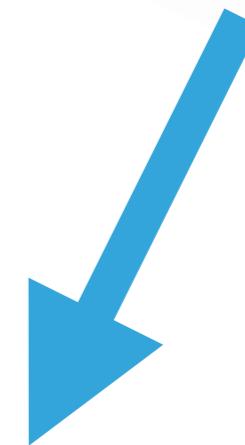
Information Source
NASA, Space.com

Call 1-800-ANRITSU to place an order or schedule a demo, or visit
www.goanritsu.com/vectorstar4

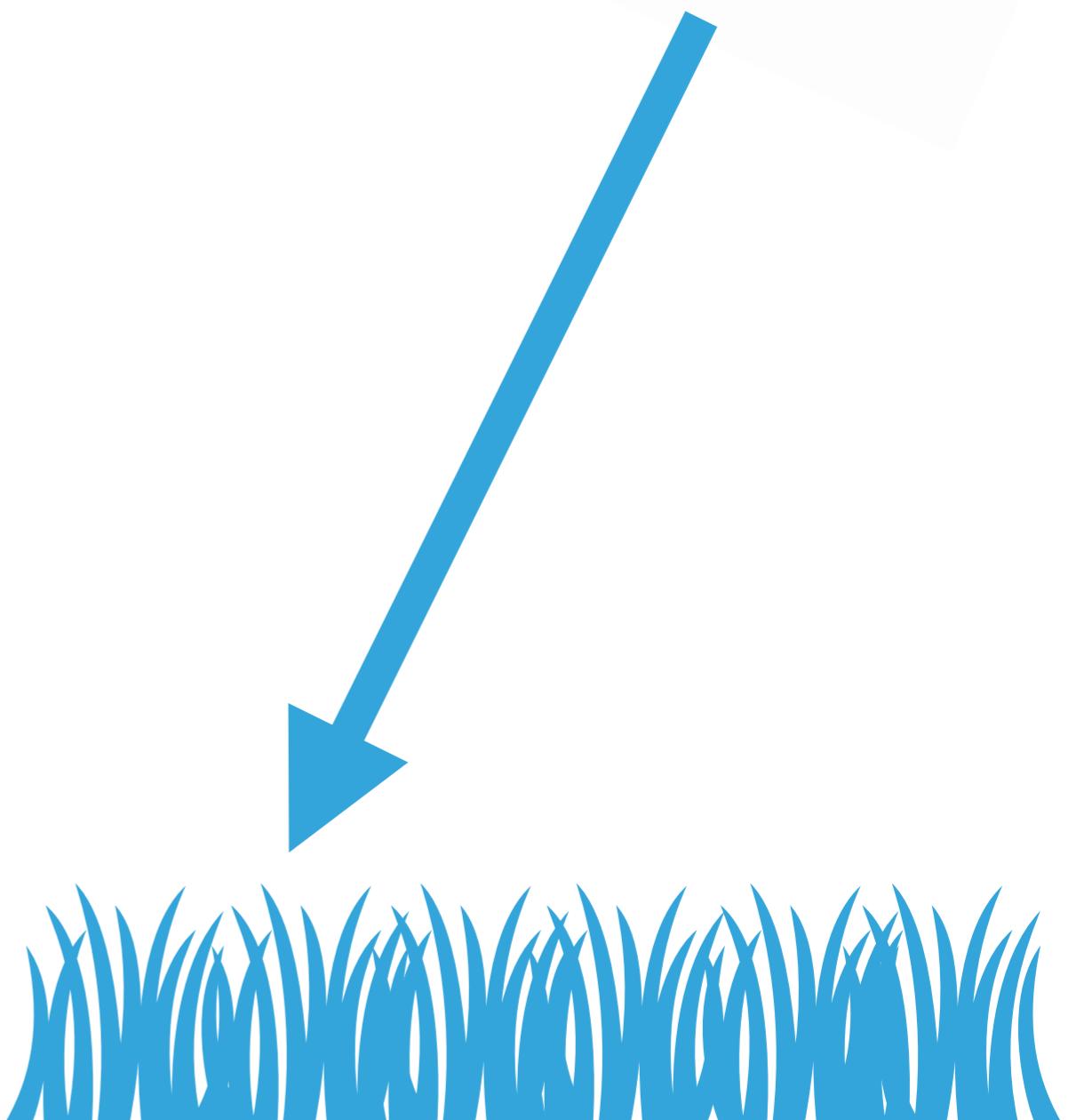
Anritsu



**FORCES NEED TO
MINIMIZED ON
LANDING FROM SPACE
TO PREVENT HARM TO
PEOPLE OR EQUIPMENT
INSIDE**



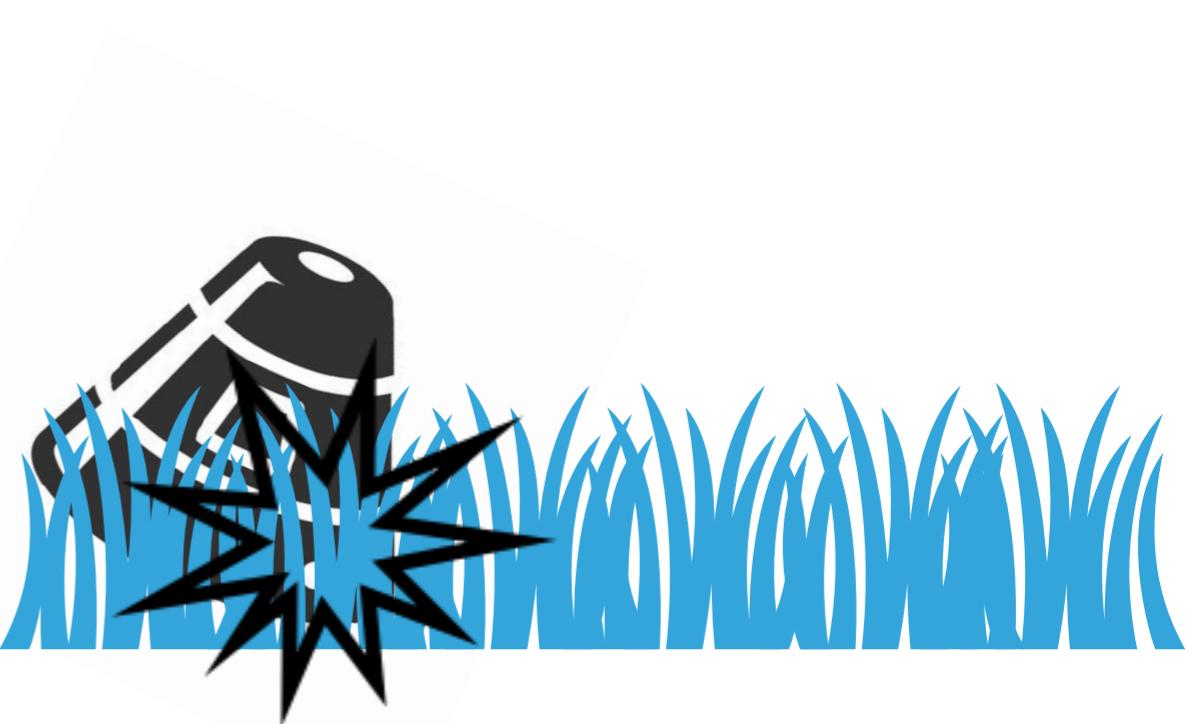
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IMPACT FORCE DETERMINED BY ACCELERATION

$$F = ma$$

Negative acceleration
(deceleration) is still
acceleration and increases
force



ACCELERATION DETERMINED BY

- ▶ impact velocity (v_{impact})
- ▶ time over which velocity changes to zero (Δt)

DECELERATION METHODS MUST EITHER

↓ v_{impact}

OR

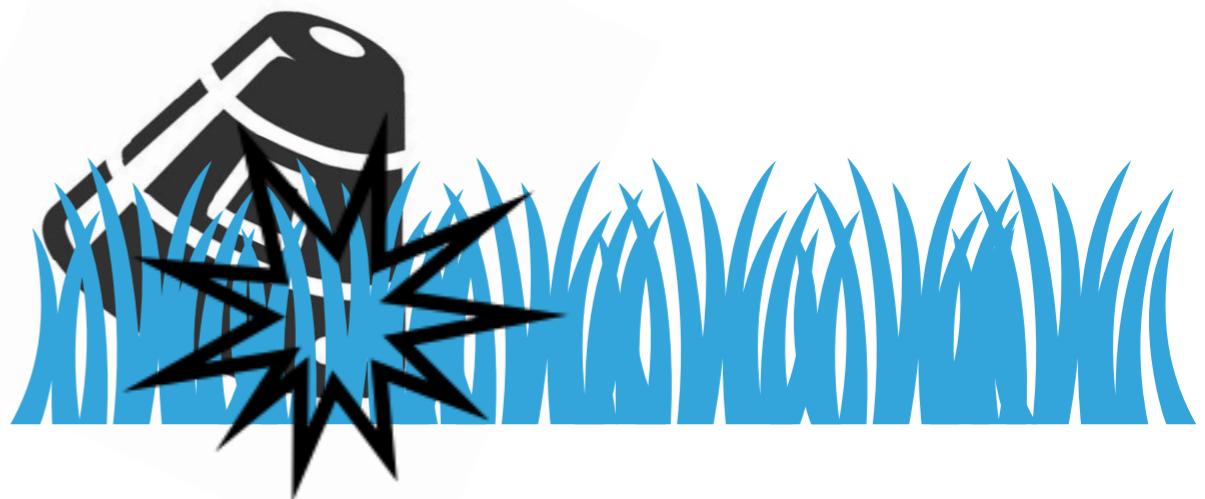
↑ Δt

$$a = \frac{\Delta v}{\Delta t} = \frac{v_{final} - v_{start}}{\Delta t}$$

$$v_{final} = 0$$

$$v_{start} = v_{impact}$$

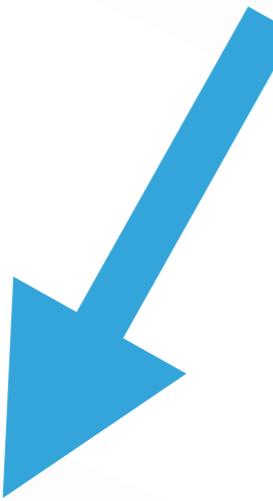
$$a = \frac{v_{impact}}{\Delta t}$$



WAYS TO DECREASE IMPACT FORCE

DECREASE

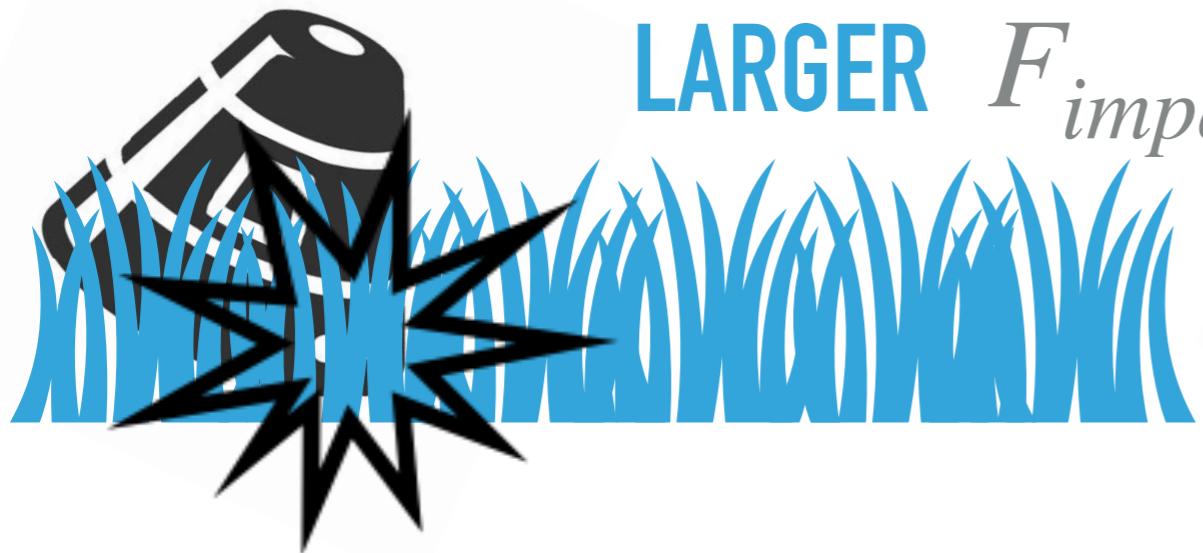
v_{impact}



LARGER v_{impact}

=

LARGER F_{impact}



SMALLER v_{impact}

=

SMALLER F_{impact}



WAYS TO DECREASE IMPACT FORCE

WAYS TO DECREASE v_{impact} ?



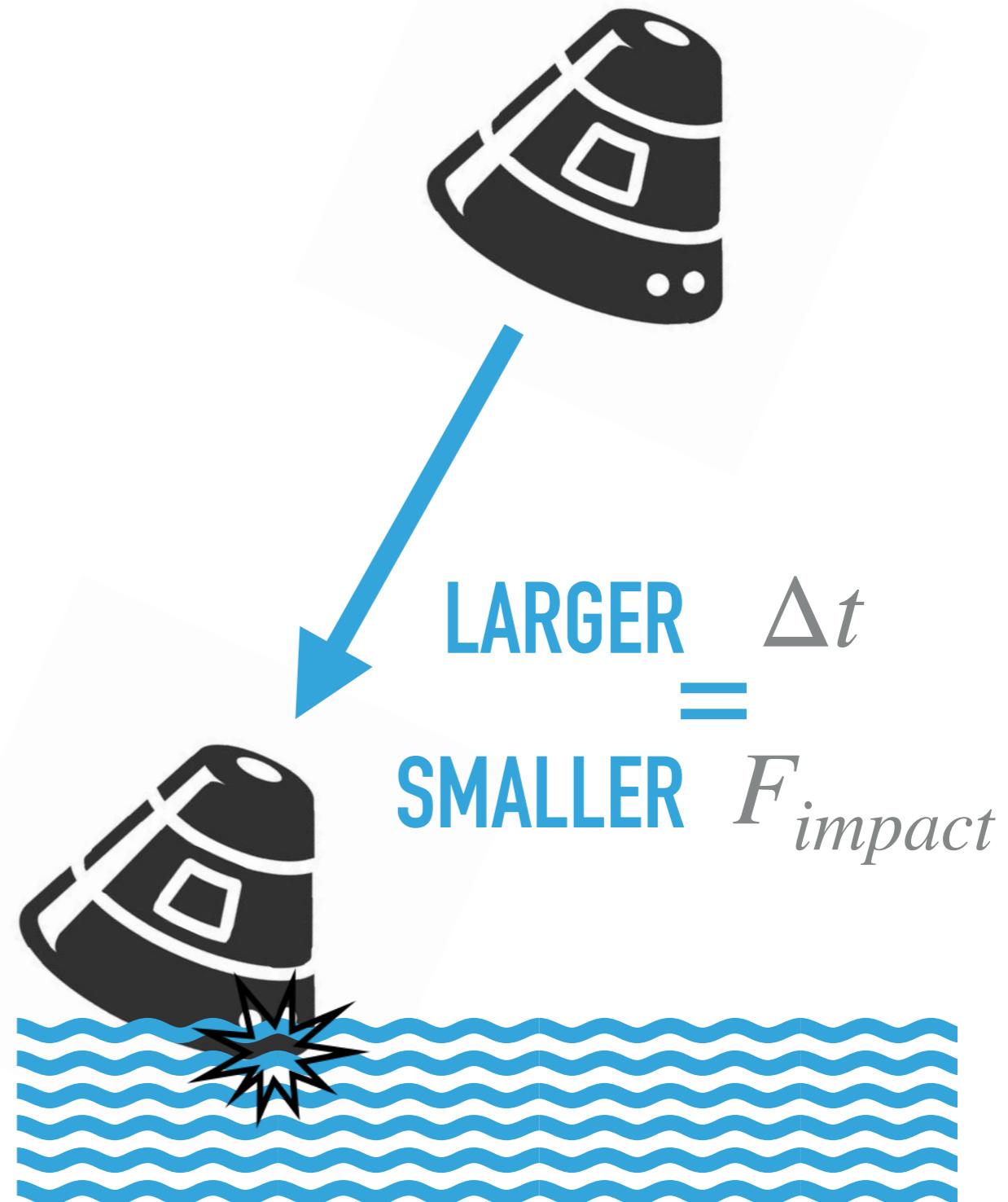
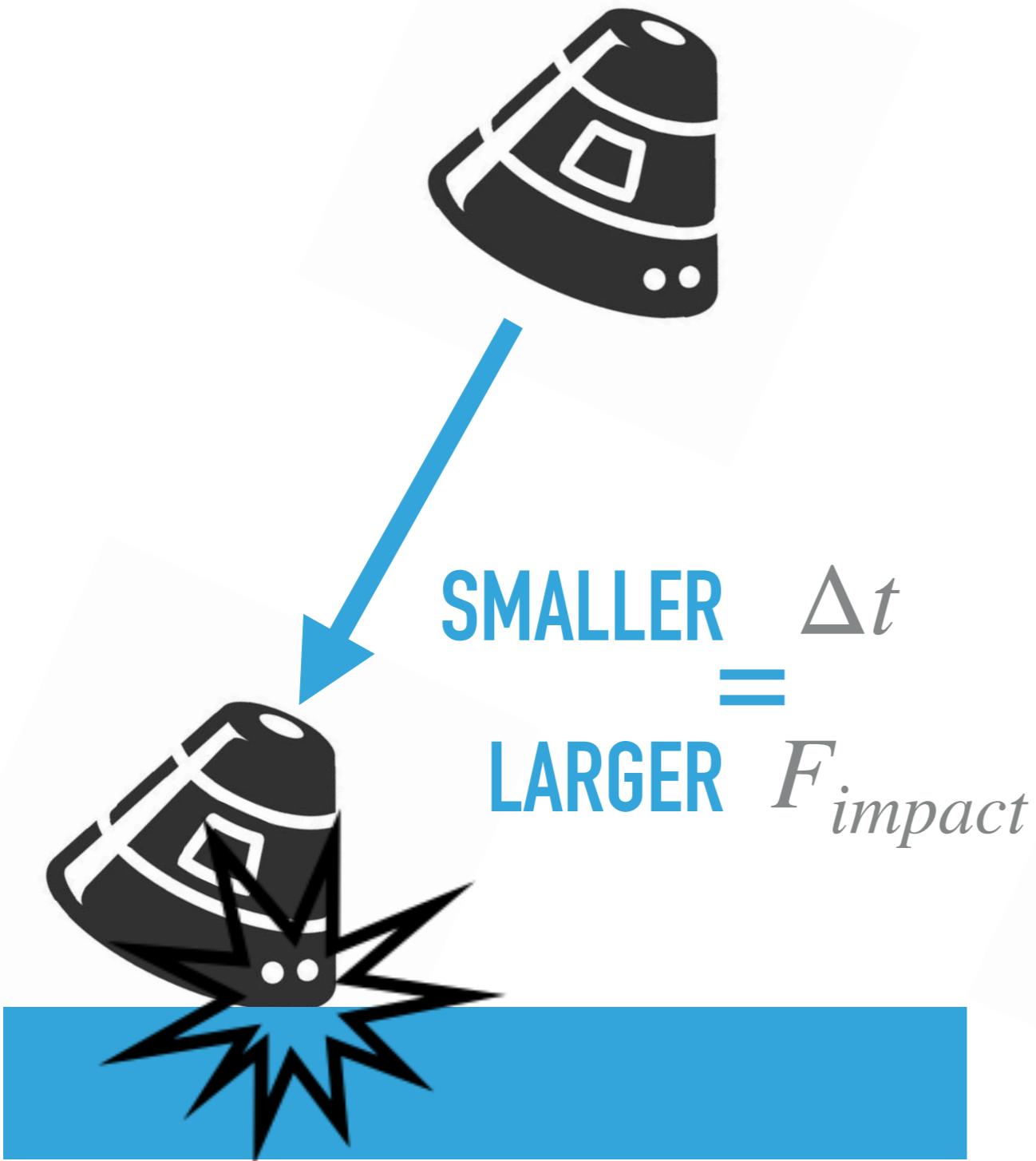
Parachutes



Landing Engines

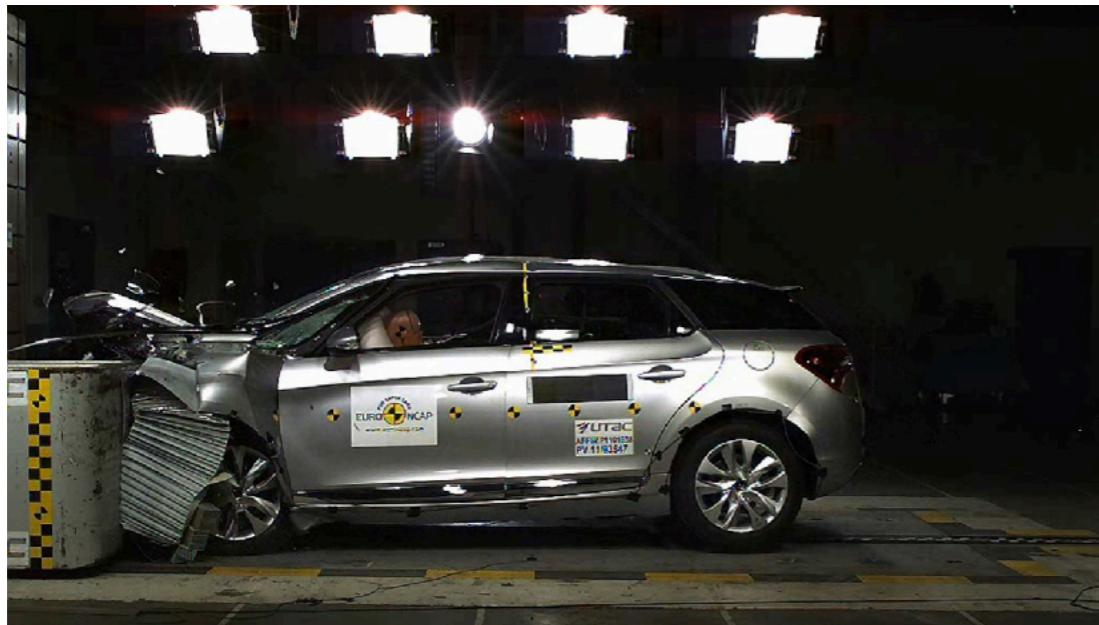
WAYS TO DECREASE IMPACT FORCE

INCREASE Δt



WAYS TO DECREASE IMPACT FORCE

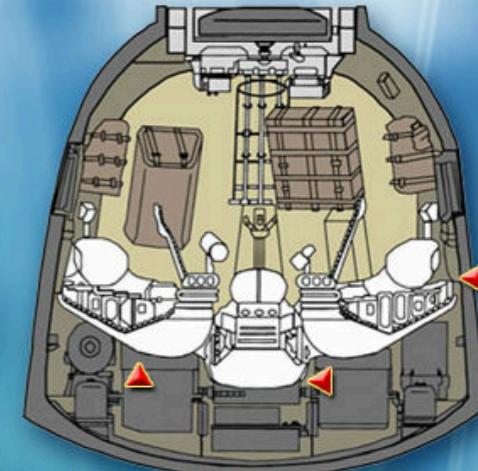
WAYS TO INCREASE Δt ?



Crumple zones

Soyuz TMA Seat Improvements

- 50 mm longer
- Max User Height - 6' 3" (*TM was 6' 0"*)
- Min User Height - 4' 11" (*TM was 5' 4"*)
- Max User Mass - 209 lb (*TM was 187 lb*)
- Min User Mass - 110 lb (*TM was 123 lb*)
- Seat Shock Absorbers Modified For New Loads
- Rerouted and redesigned avionics



Payload Cushioning

THE ACTIVITY: DIGITAL EGG DROP

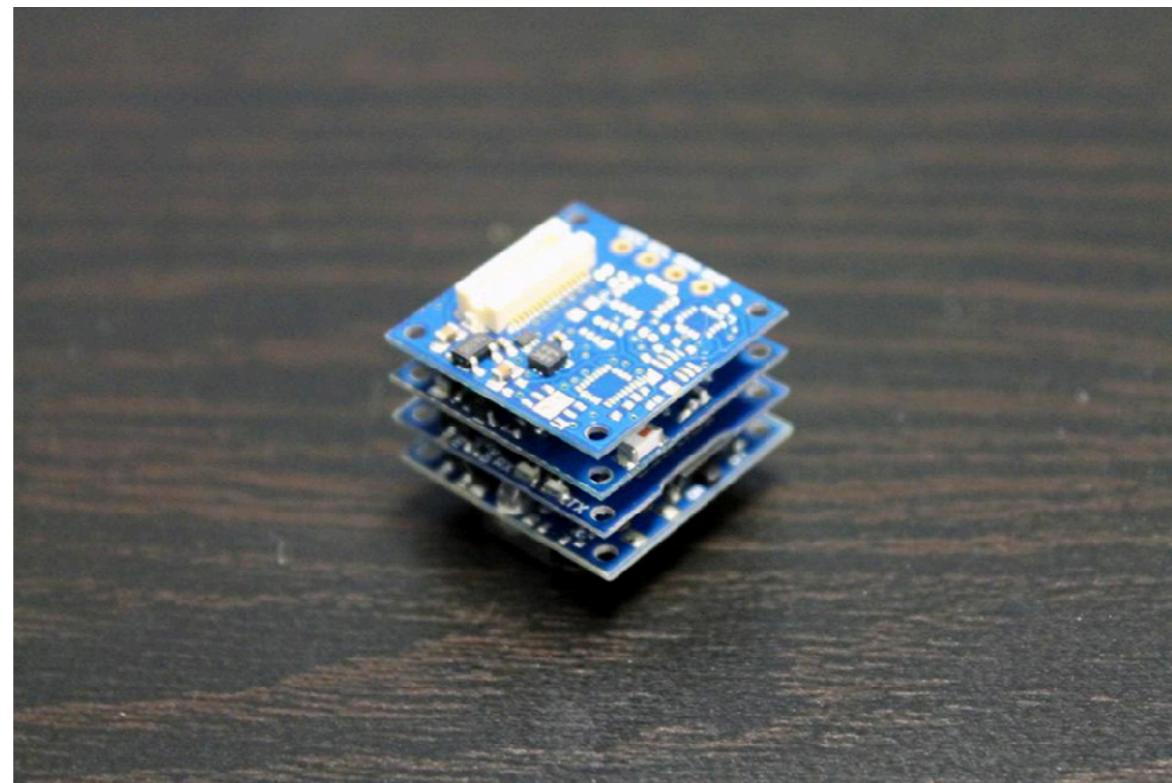
DESIGN A LANDING CAPSULE TO PROTECT A DIGITAL “EGG”

- ▶ Materials:
 - ▶ Masking tape
 - ▶ 8" x 11" paper sheets
 - ▶ DigiEgg (Bluetooth enabled accelerometer)
- ▶ Methods
 - ▶ 30 min to design a capsule
 - ▶ Record 3 times each (taking the largest value after free fall)
 - ▶ Winning design has the smallest average acceleration

MATERIALS

DIGIEGG

- ▶ Micro-controller with a 3D accelerometer
- ▶ Total acceleration transmitted via Bluetooth to phone



<http://iotdesign.embedded-computing.com/articles/build-an-internet-connected-bluetooth-wearable-with-arduino-and-cordova-part-one/>

DIGIEGG

- 1.What should the acceleration be at rest?
- 2.What should the acceleration be during free fall?
- 3.Will the acceleration at impact be larger or smaller than your answers to 1?
- 4.Will the acceleration at impact be larger or smaller than your answers to 2?