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).

Entry Interface
10:10:46 PM PDT
10:24:34 PM PDT

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

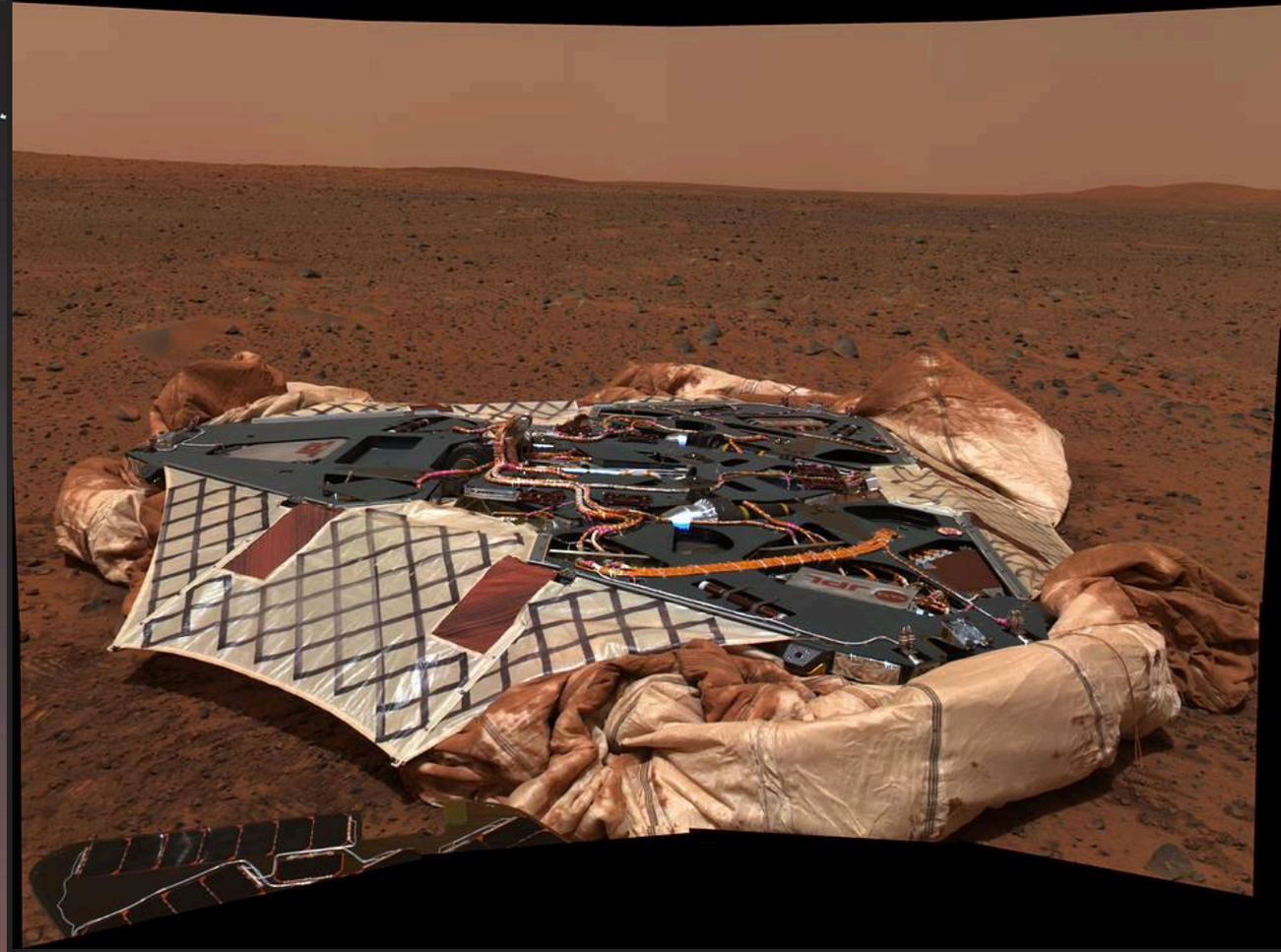
The parachute deploys
at an altitude of 7 miles (11 km) and the heat shield falls away. At this point speed is about 900 mph (1450 kph).

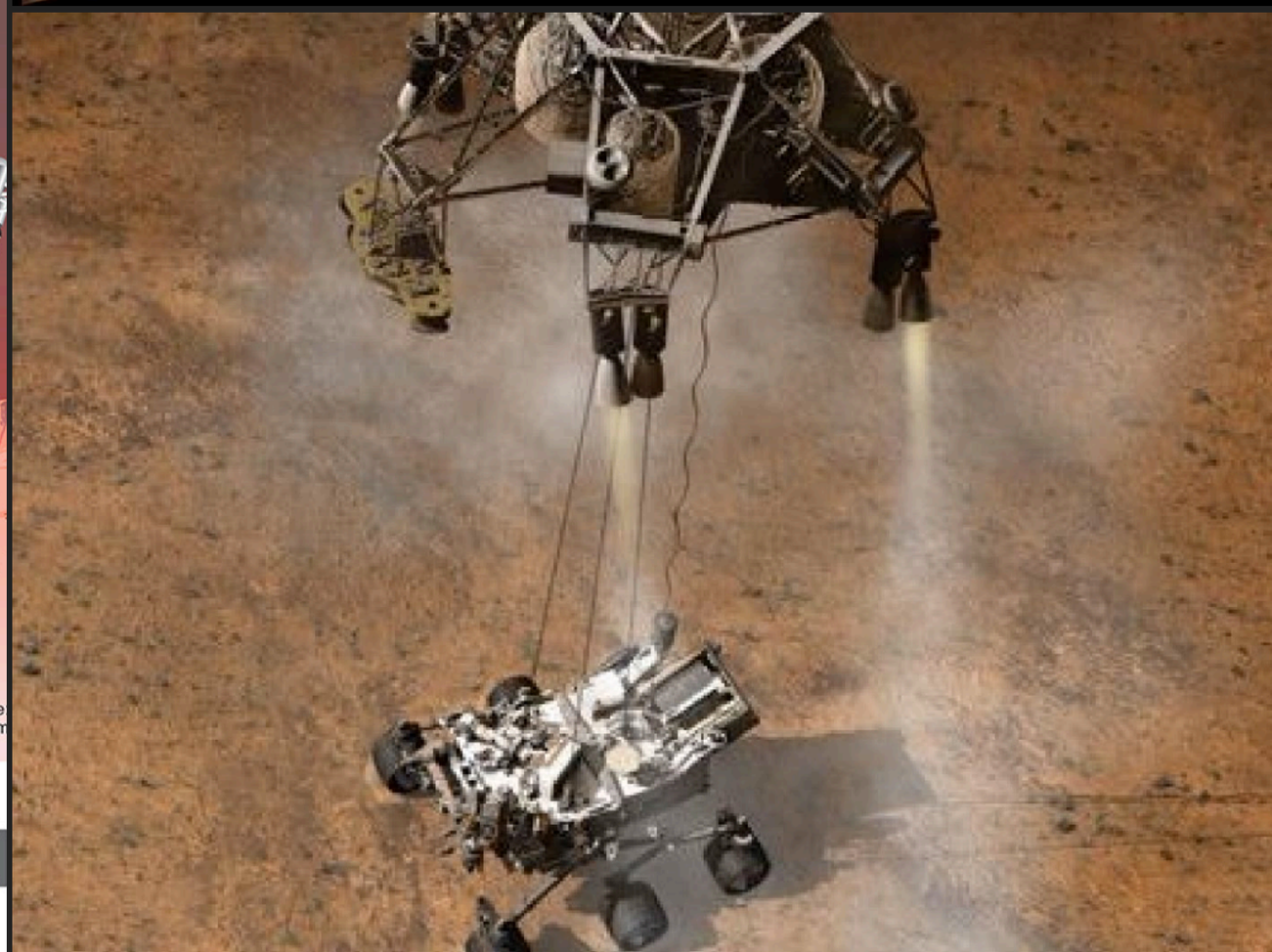
Heatshield Separation
10:15:25 PM PDT
10:29:13 PM PDT

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

Information Source
NASA, Space.com





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

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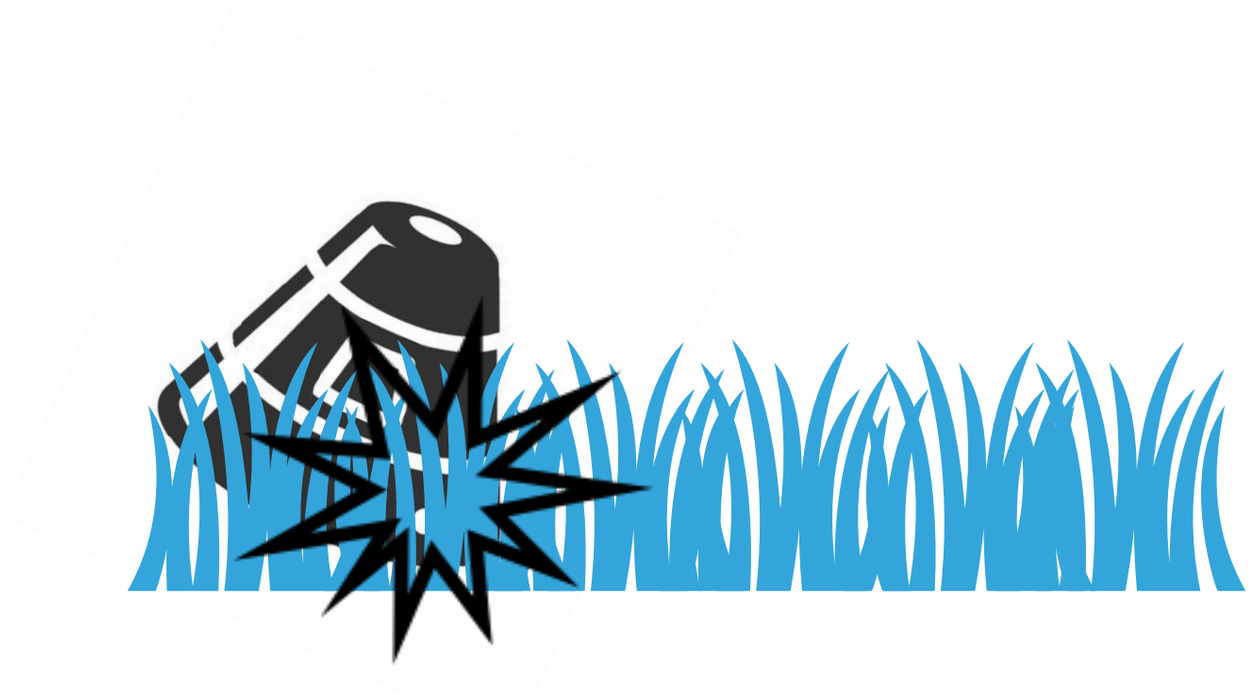
IMPACT FORCE DETERMINED BY ACCELERATION

$$F = ma$$

Negative acceleration (deceleration) is still acceleration and increases force



ACCELERATION DETERMINED BY

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

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

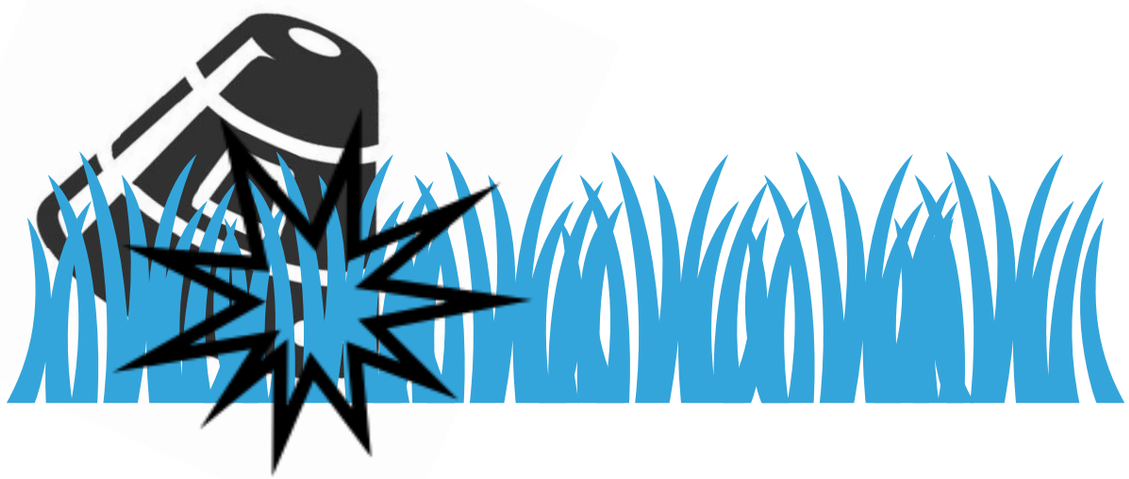
$$v_{final} = 0$$

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

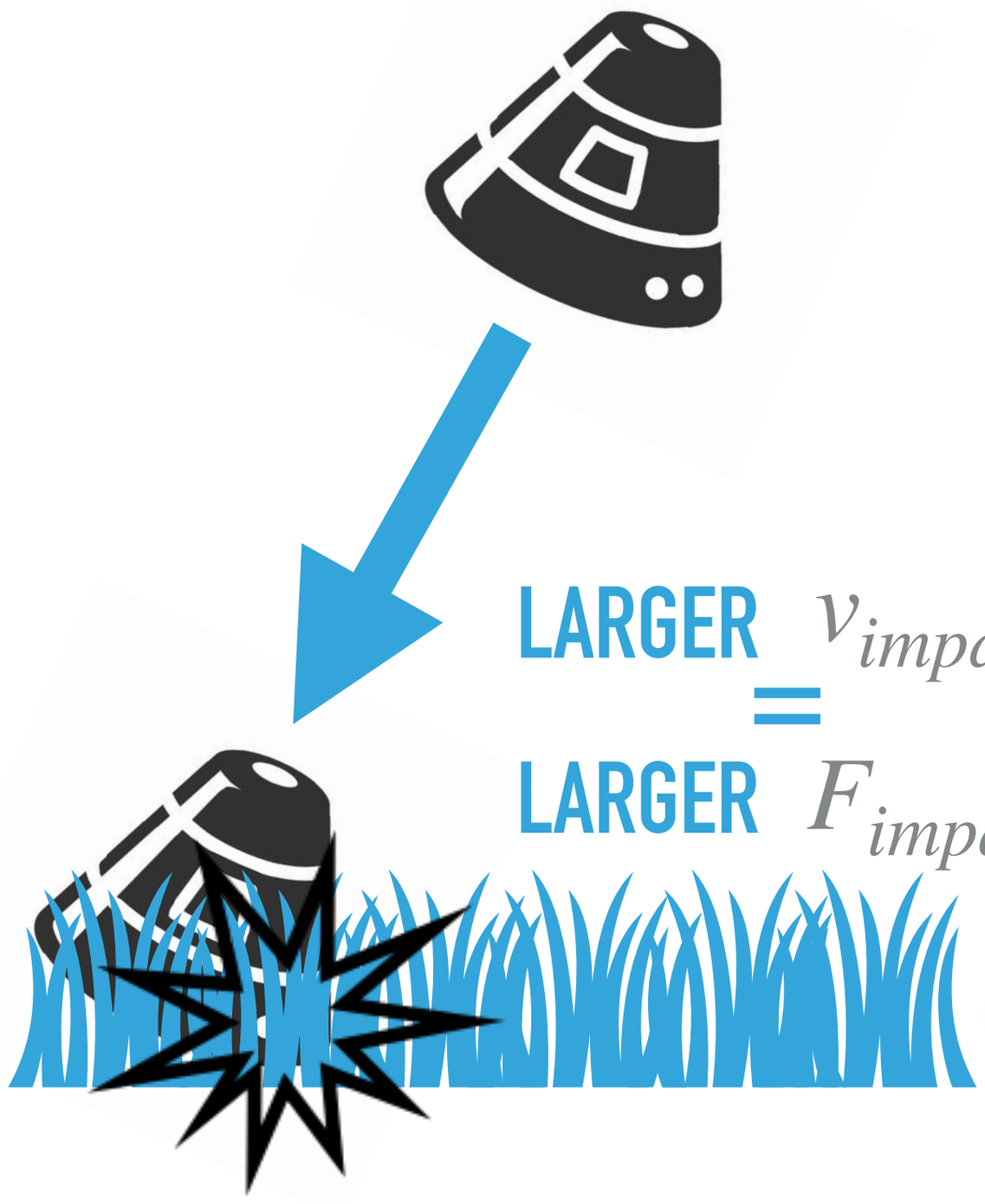
$$a = \frac{v_{impact}}{\Delta t}$$

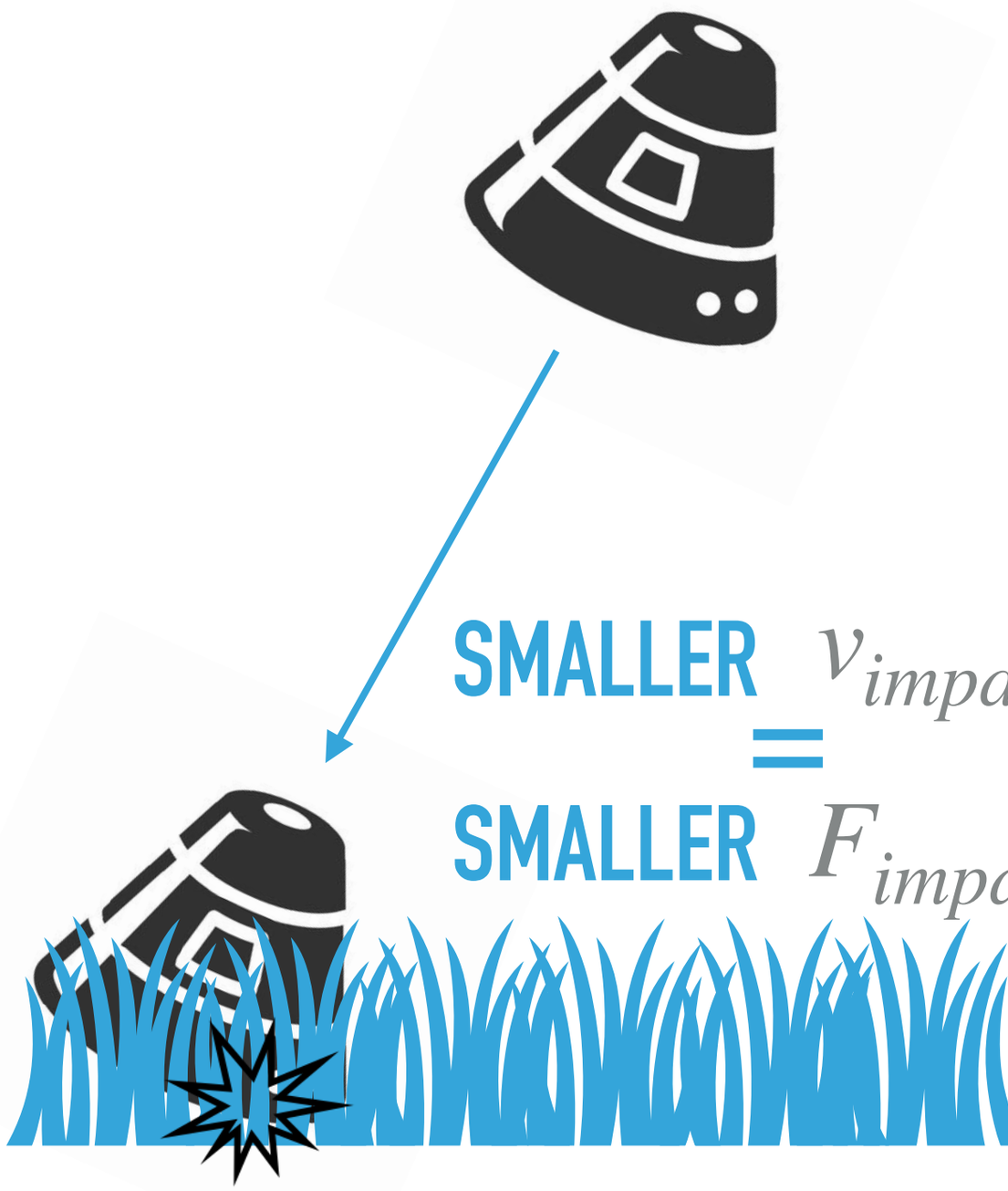
DECELERATION METHODS MUST EITHER

$\downarrow v_{impact}$ **OR** $\uparrow \Delta t$

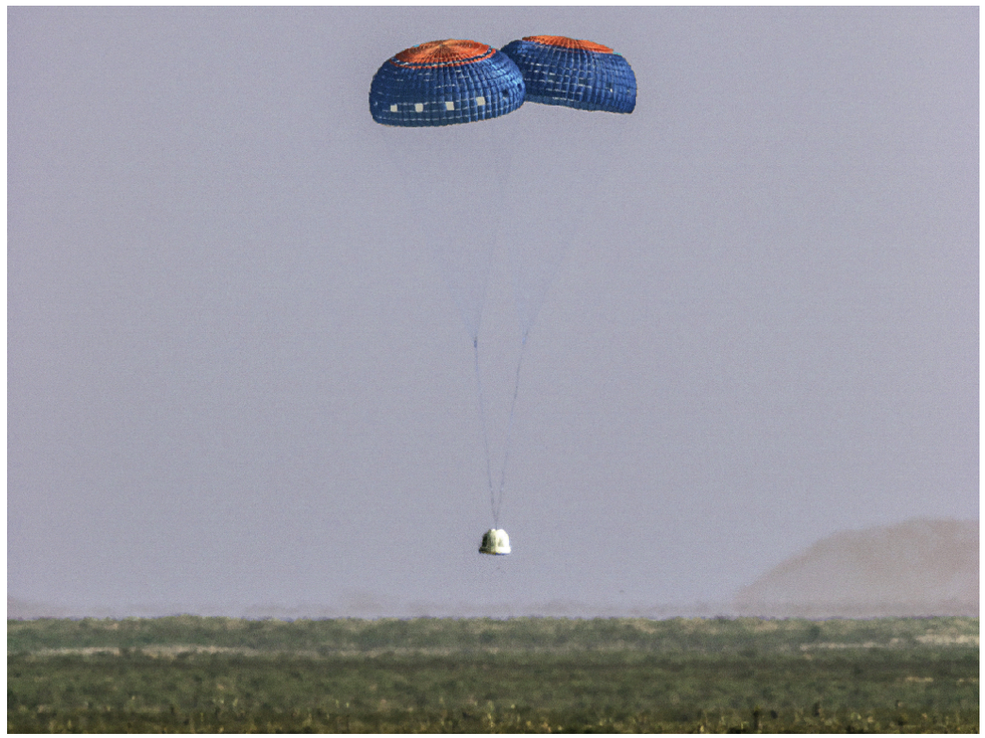


DECREASE v_{impact}





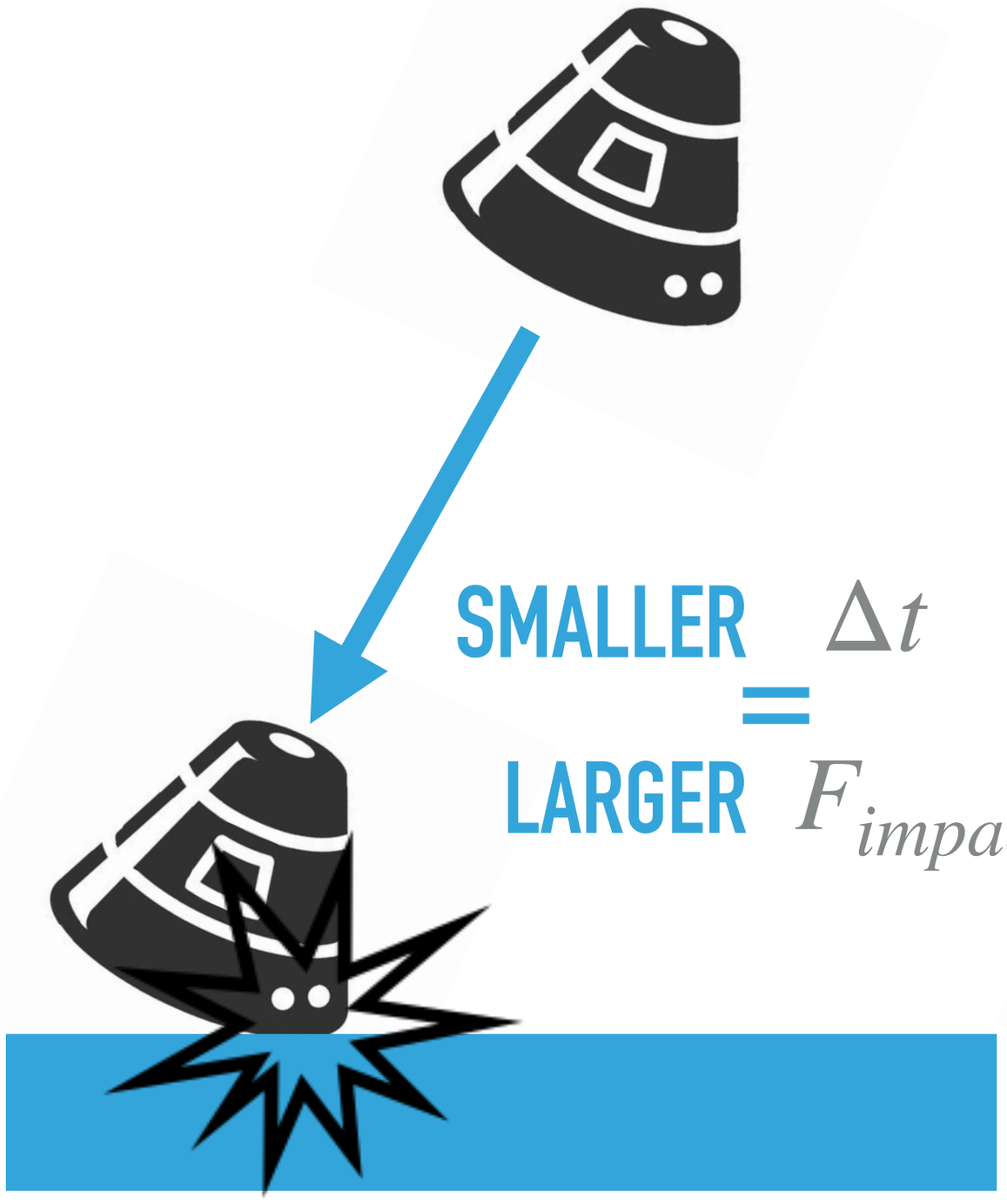
WAYS TO DECREASE v_{impact} ?

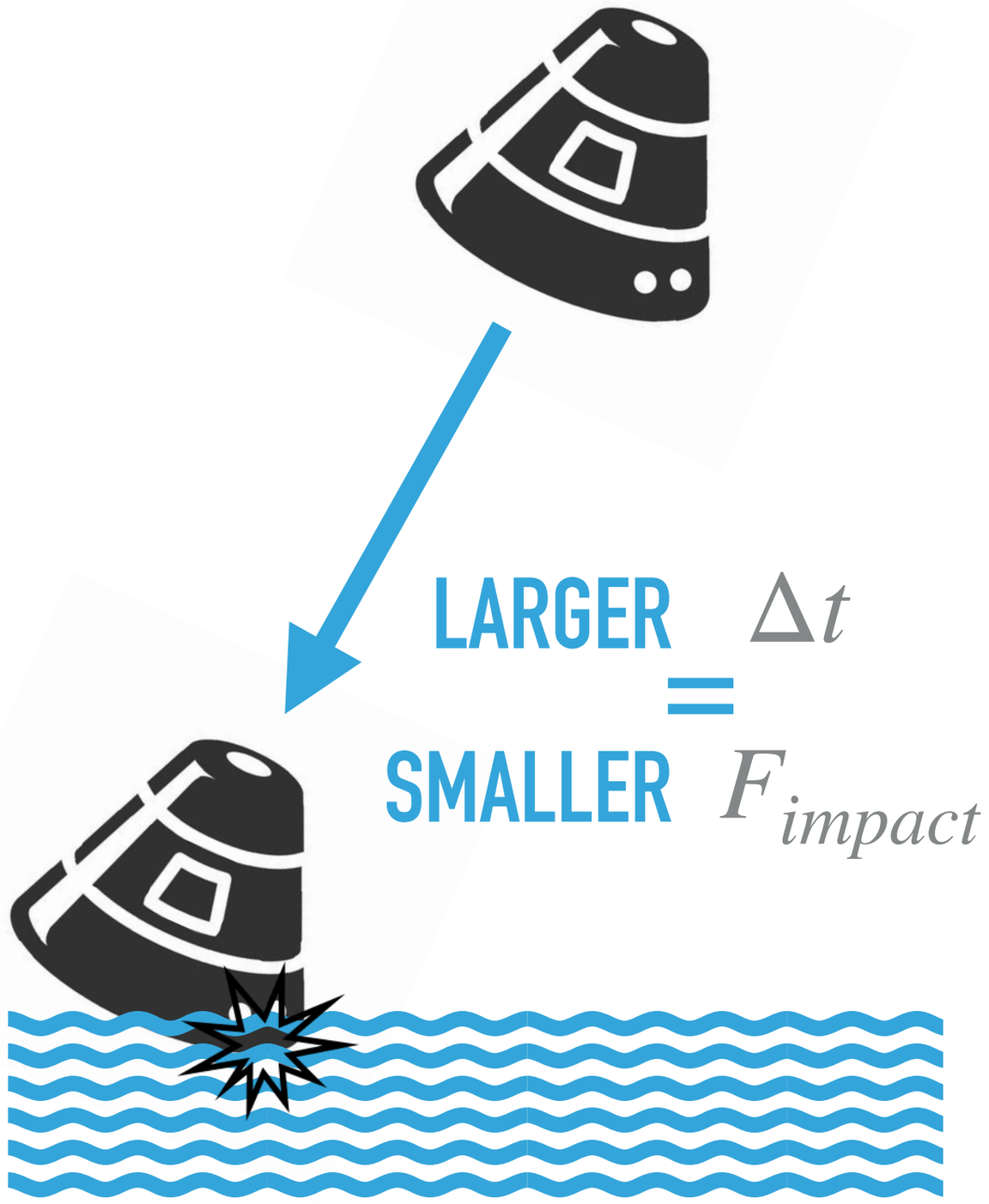


Parachutes

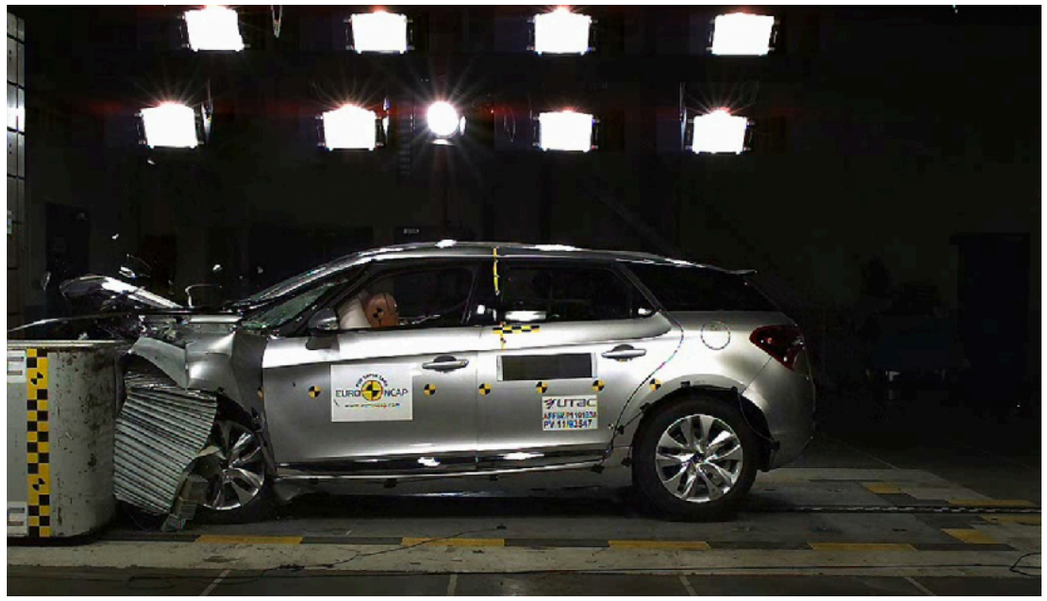
Landing Engines

INCREASE Δt

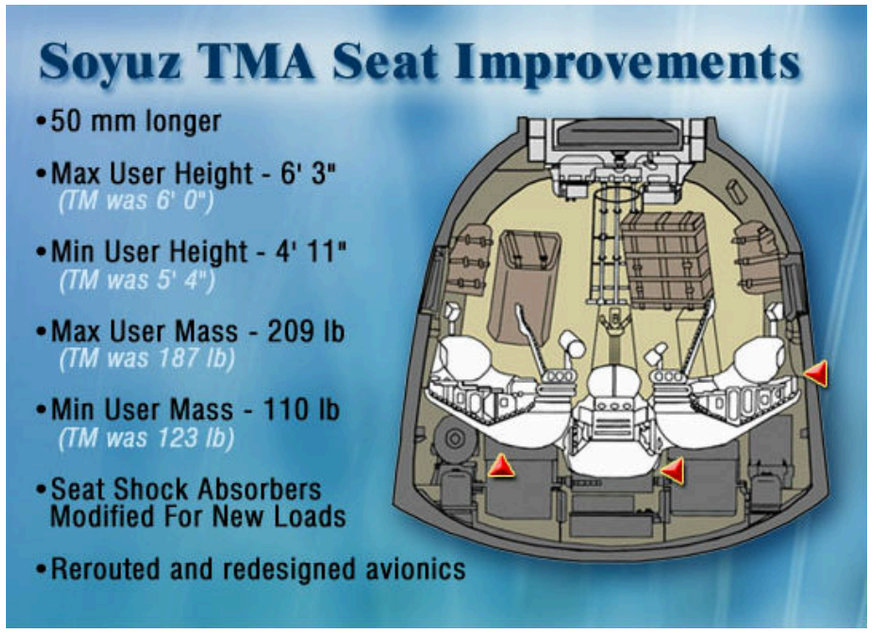




WAYS TO INCREASE Δt ?



Crumple zones



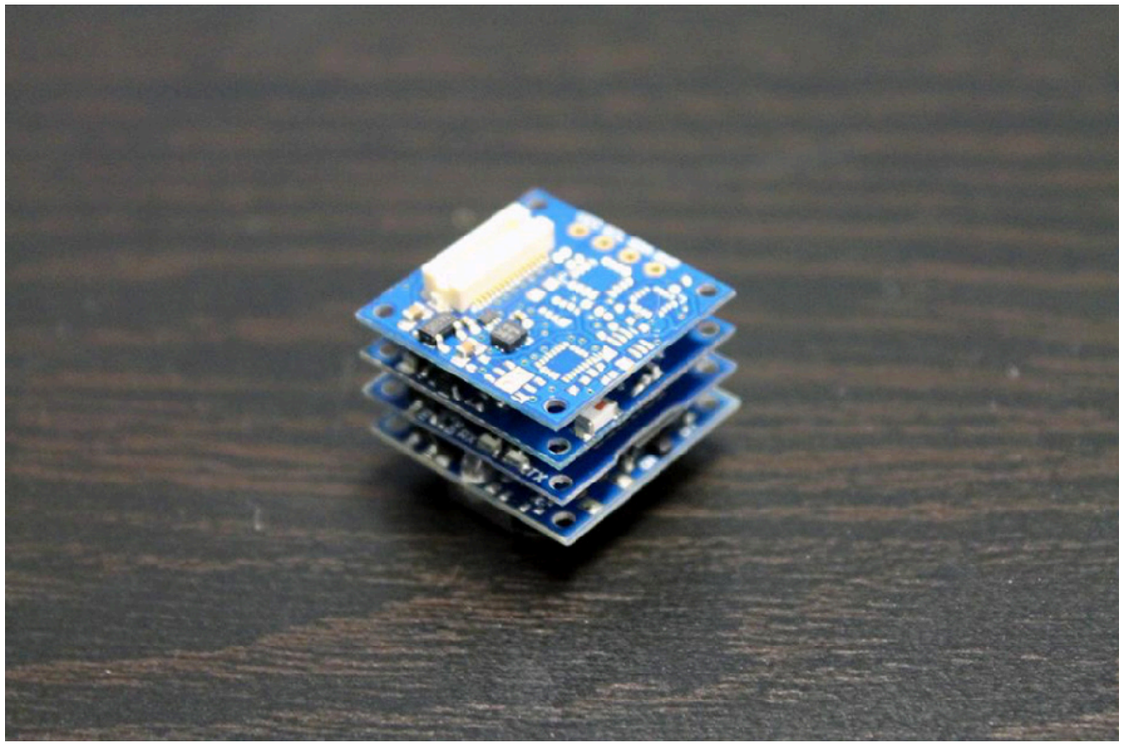
Payload Cushioning

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

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?