National Aeronautics and Space Administration

MONEY MA$$-EMATICS

Ratios and Percentages with Laser Communications

When we say the word “spacecraft,” a lot of people imagine rockets taking off, but the rockets are just a tool to get our satellites and spacecraft to their destination: space. Once a satellite reaches its destination, **payloads** onboard start conducting science and capturing information – data – about space. On Earth, NASA’s space communications team makes sure we can get that data home. Traditionally, NASA uses radio communication systems to talk with spacecraft, but payloads like ILLUMA-T[1] will allow us to share information using lasers.

Laser communications systems send information with invisible infrared light waves, which allow missions to send more information at once than with radio waves. Another benefit is that laser communications systems typically have **less mass**. Every kilogram (kg) of mass increases the costs and energy NASA needs for a space launch. These costs include paying for rockets, fuel, and the people who build and operate those rockets. Exploring lighter communications systems, like laser communications, could reduce the mass of the whole spacecraft. Less mass will mean less cost in the future, giving NASA the power to explore more of our universe than ever before!

GRADES:
7 & 8

STANDARDS:
CCSS.MATH.CONTENT.7-8.RPA.3:
Ratios & Proportional Relations

MATERIALS

- Calculator (optional)
- Scratch paper
- Pencil

Example

If each kilogram costs $4,990 to launch, how much would it cost to launch a 2L bottle of juice into orbit?

$$2L * \frac{1\ kg}{1\ L} * \frac{\$4{,}990}{1\ kg} = \$?$$

↓

$$2\cancel{L} * \frac{1\ \cancel{kg}}{1\ \cancel{L}} * \frac{\$4{,}990}{1\ \cancel{kg}} = \$9{,}980$$

What is *your* mass? Convert your **mass** from pounds (lbs) to kilograms (kg). You may recall that 2.20 pounds equals about one kilogram.

$$\text{your mass } lb * \frac{1\ kg}{2.20\ lb} = \_\_\_\_\_\_\ kg$$

How much would it cost to fly you into a similar orbit? You can calculate your launch cost by converting that mass to cost in dollars!

$$\text{your mass } kg * \frac{\$4{,}990}{1\ kg} = \$\ \_\_\_\_\_\_\_\_$$

WHAT IS A KILOGRAM, ANYWAY?

The metric unit for mass is the kilogram – 1,000 grams – which weighs 2.20 pounds on Earth. Some other things that have the mass of about one kilogram:

- **17 tennis balls**
- **2 soccer balls**
- **150 pencils**
- **10 peanut butter & jelly sandwiches**

One liter (L) of water has a mass of **exactly** one kilogram; grams and kilograms were designed all the way back in 1795 to represent a specific mass of water!

[1] This stands for “Integrated LCRD Low-Earth Orbit User Modem and Amplifier Terminal”: see **https://esc.gsfc.nasa.gov/projects/ILLUMA-T/**

Now it's your turn to be a NASA **resource analyst** and help us keep our missions in budget. This kind of analysis involves a lot more than figuring out how much fuel you might save — you'll need to help us figure out if we can fit our mission on a smaller rocket and save even *more* money for future missions!

Calculating costs is an important piece of launching a payload like ILLUMA-T. Let's imagine it's 2050, and NASA is building a mission that costs $4,990 for each kilogram we want to put into **orbit** (anything in space that moves around a moon, star, or planet in a set pattern is **in orbit**). Heavier objects cost more to launch.

NASA is funded by the U.S. government. Resource analysts keep our spending smart! They help NASA projects understand how much they can spend, track how much money is spent, and make sure that everyone is paid for their work.

Nylsevalis "Nylse" Ortiz-Collazo is the Deputy Project Manager of Resources for ILLUMA-T. She oversees the resource analysts that monitor if a project's costs equal its benefits, schedulers that manage the payload calendar, and engineers who balance project risks. Nylse has worked for NASA for over 20 years and loved space ever since she was a kid!

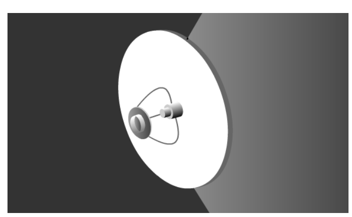
1. Now it's time to be mission planners for ILLUMA-T's launch! If the fuel for launching our fifteenth-generation ILLUMA-T on our futuristic (imaginary) CLNSWP-7 rocket costs **$2,205,580**, what is the mass of ILLUMA-T? We can reverse the equation you used above to calculate the launch costs. Instead of using your mass, we will use the launch cost to find out the payload's mass.

$$cost * \frac{mass\ unit}{cost\ per\ mass\ unit} = mass$$

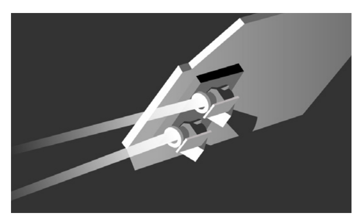
$$mass = \$2{,}205{,}580 * \frac{1\ kg}{\$4{,}990} = \underline{\hspace{3cm}}$$

We'll use your answer for ILLUMA-T's payload mass for the rest of this worksheet.

2. Percentages are helpful tools to quickly understand differences in numbers. Part of the mass of our spacecraft is a **76 kg** radio. If a laser telescope from ILLUMA-T has only 25% of the **mass** of the radio, what is the mass of the laser telescope?



Radio system: 76 kg



Laser telescope: _______ kg

We'll use the same **masses** for our radio and laser systems in the rest of the worksheet.

3. If we replace the radio with a laser communications system, by what percentage have we reduced the mass of the entire payload? Remember that the communications systems are just one part of the payload; there are other systems on board which have mass!

   (Hint: Calculate the new mass, then divide the new mass by the old mass. This gives us the ***percentage****, or the proportion, of the old mass the new mass represents. Subtract that overall percentage from 100% to get the* ***percentage reduction****.)*

$$mass_{new} = mass_{old} - mass_{radio} + mass_{telescope}$$

$$\_\_\_\_\_\_\_\_\_ \; kg = \_\_\_\_\_\_\_\_\_ \; kg - \_\_\_\_\_\_\_\_\_ \; kg + \_\_\_\_\_\_\_\_\_ \; kg$$

$$percentage\ of\ old\ mass = \frac{new\ mass}{old\ mass} \qquad \_\_\_\_\_\_\_\_\_ \; \% = \frac{\_\_\_\_\_\_\_\_\_ \; kg}{\_\_\_\_\_\_\_\_\_ \; kg}$$

4. How many dollars does it cost to launch the payload with a radio system? How much might it cost in the future to launch the payload with the laser system? Use similar ratios to calculate the potential cost savings of a future optical network. Consider starting by listing the **units you're calculating** (like we've been doing in examples above) before using actual numbers.

5. Now we know the percentage of **mass** that we could save with the laser system. By what percentage could we reduce **cost**? Is the cost reduction different from the mass reduction? Why?

6. Future laser communications systems could let us use smaller, cheaper rockets for our lighter **payload** mass. Can NASA's future use of laser communications reduce the mass of our payloads enough to meet the standards for any of the imaginary rocket options available below?

 Decide which rocket is the most cost-effective for our 2050 launch. If we make no changes, we can **still afford** the CLNSWP-7; radio communications is already cost-effective, and our project manager has reserved the money in the budget.

	Necessary Mass Reduction	**Rocket Price**	**Transportation Cost to Launchpad**
Rocket CLNSWP-7	0% (current plan)	$4,130,000	$96,380
Rocket NMBS-2K	10% to 15%	$3,923,000	$74,200
Rocket COMET-180	More than 15%	$3,406,000	$63,900

7. **Bonus Question:** If we can reduce our mass enough to use either of the smaller rockets, what are the **total potential** cost savings? You will need to account for fuel savings from our mass reduction, rocket prices, and transportation costs!

NASA's **Integrated LCRD Low-Earth Orbit User Modem and Amplifier Terminal (ILLUMA-T)** flies aboard the International Space Station, and can offer new capabilities to the astronauts living and working there. Laser communications enable missions to transmit more data per transmission. More data from space allows NASA to make more discoveries about our planet, microgravity, and the human spaceflight experience.

ILLUMA-T sends data from the space station to the Laser Communications Relay Demonstration (LCRD) at 1.2 gigabits per second. LCRD, as a relay satellite, sends the data down to ground stations in Haleakalā, Hawaii or Table Mountain, California. Together, LCRD and ILLUMA-T form the first fully operational end-to-end laser communications system.

Laser communications systems provide numerous benefits to missions, including improved size, mass, and power requirements over comparable radio systems. The smaller size makes more room on the spacecraft for other science instruments. Less mass enables cost savings. Less power drain means electric power systems last longer. These benefits are essential for missions as we explore further into space.

To learn more about ILLUMA-T:

International Space Station - https://go.nasa.gov/3qQQ7Lq
Laser Communications Relay Demonstration (LCRD) - https://go.nasa.gov/3svYnBi
NASA Laser Communication Payload Undergoing Integration and Testing - https://go.nasa.gov/40e53zU
NASA Laser Communications Innovations: A Timeline - https://go.nasa.gov/40bxQF3
Women of Space Communications & Navigation, featuring Nylse Ortiz-Collazo - https://go.nasa.gov/3ZQZ9Ur