### Course compass

Question directrice : How do coordinates describe position, why do they depend on the chosen frame, and how can convention errors be prevented?

> Open educational resource: this content is not professional training, a diploma, certification, or authorization. Examples are educational and do not replace engineering, testing, and qualification of real space hardware.

---

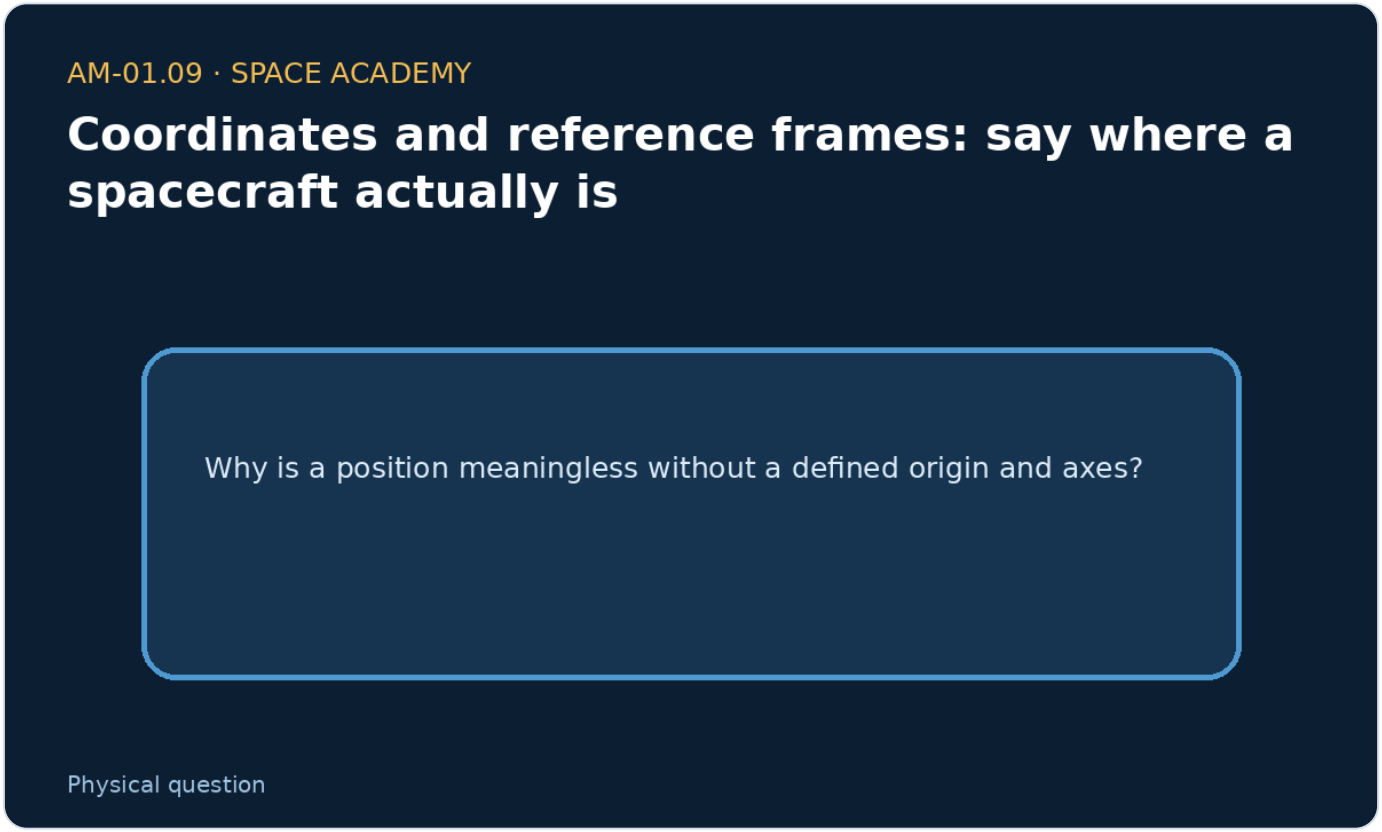
# 1 — A coordinate frame is a map with a chosen starting point

To say where a rover is, “over there” is not enough. We need a shared rule for measuring position.

A **coordinate frame** specifies an **origin**, one or more measurement directions called axes, a unit, and a positive direction for each axis.

## Origin

The **origin** is the point assigned position zero, often labelled O. On a local Mars-base map it might be the centre of an airlock, a beacon or a surveyed marker.




Before reading coordinates, know where zero is and which way the axes point.

## 2 — What do x, y and the parentheses mean?

In a two-dimensional plane we often use **x** for horizontal and **y** for vertical on the map.

A position such as `(4, 3)` is read “four, three”. The first number is x; the second is y.

### Rover at (4, 3)

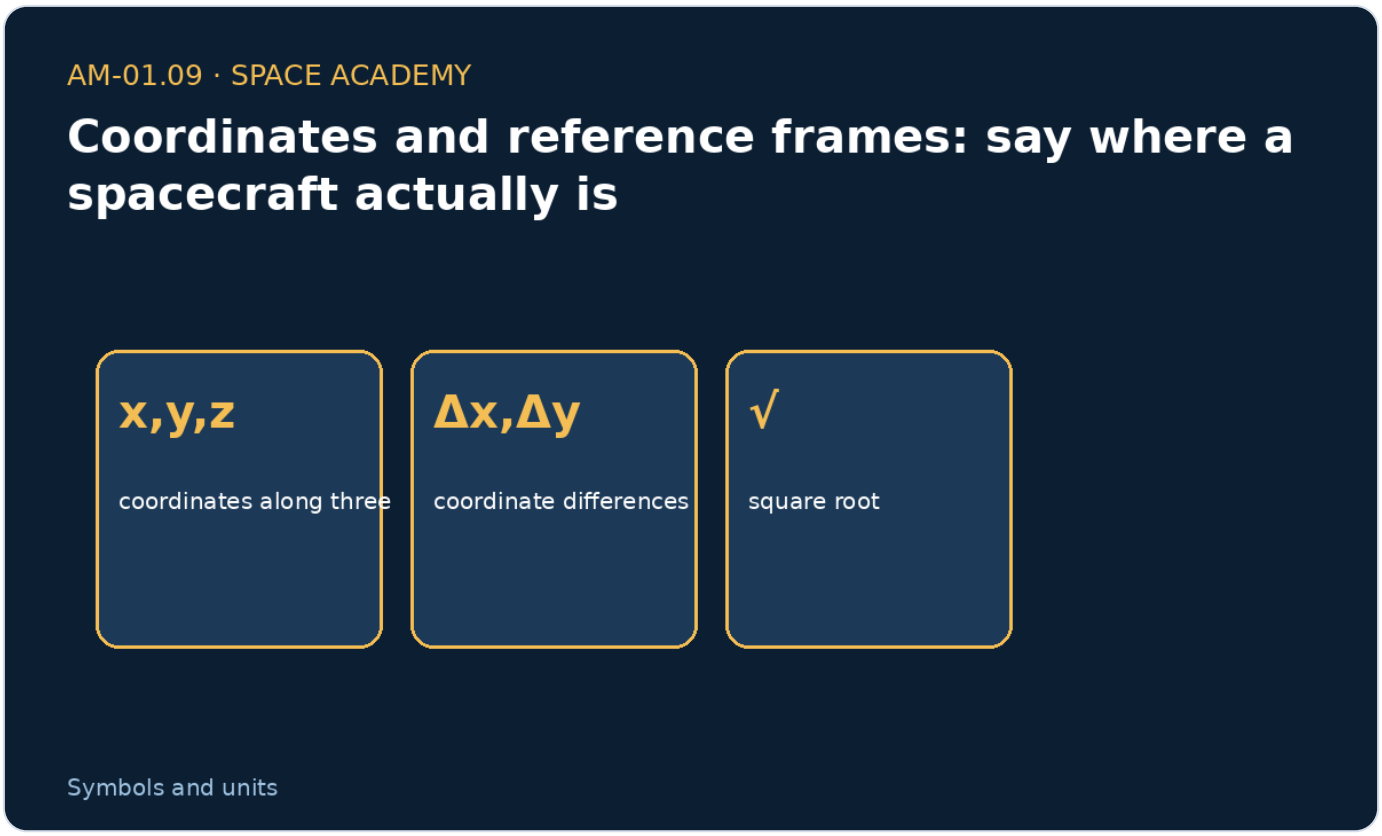
If the unit is metres, move 4 m in positive x and 3 m in positive y from the origin. The rover did not necessarily travel along those two legs; coordinates describe its final position.

## 3 — Why can coordinates be negative?

Plus and minus signs distinguish opposite directions on the same axis. If right is positive x, left is negative x. If north/up on the map is positive y, the other direction is negative y.

### Example

`(−2, 5)` means 2 units in negative x and 5 units in positive y. −2 does not mean an impossible negative distance; it identifies which side of the origin the point lies on.




The sign identifies the side of the origin.

# 4 — Concrete example: rover, habitat and antenna

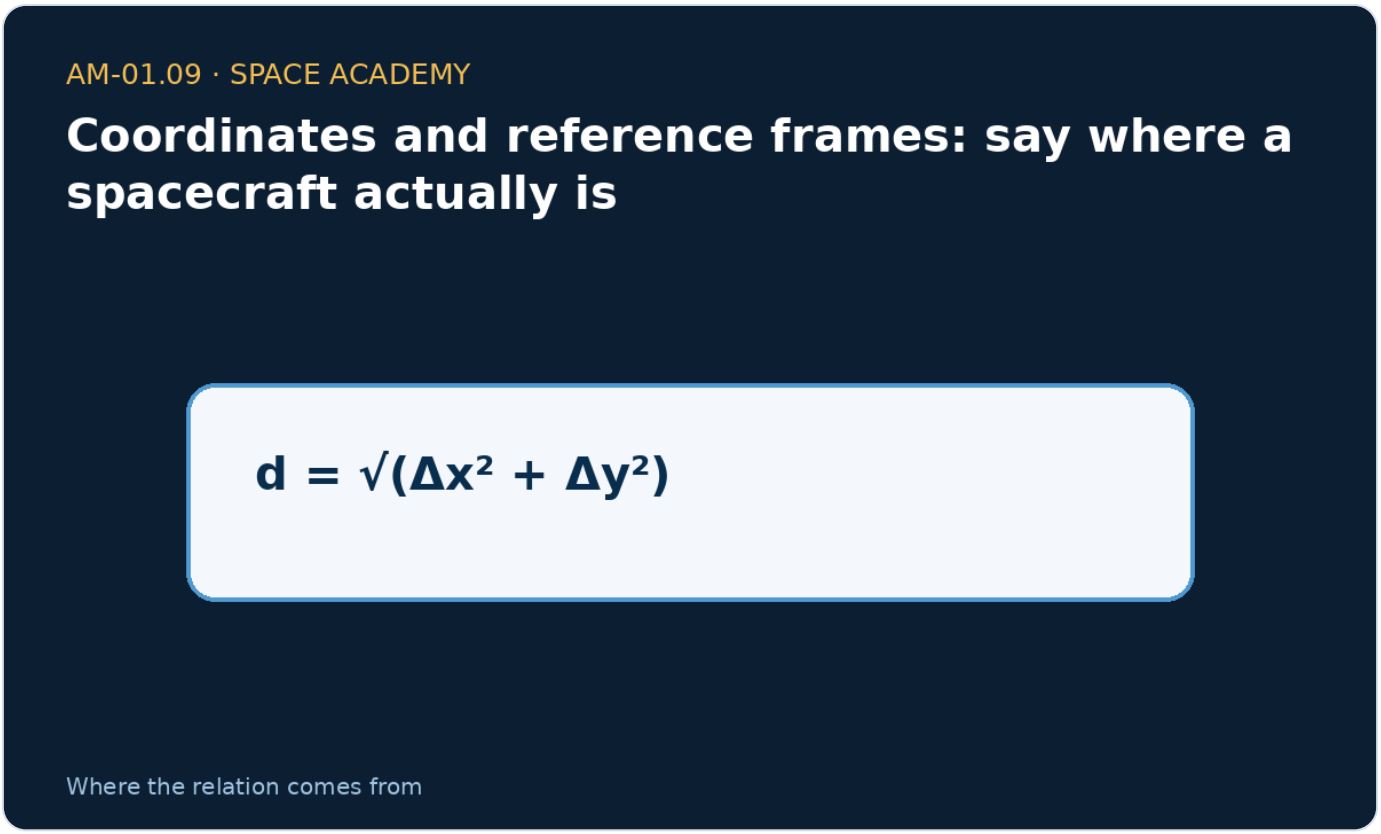
Origin at the habitat. Positive x points east, positive y north. Unit: metre.

- Habitat: (0, 0).
- Antenna: (30, 0) — 30 m east.
- Rover: (30, 40) — 30 m east and 40 m north.

## Direct habitat-rover distance

$\text{distance} = \sqrt{(30^2 + 40^2)} = \sqrt{2500} = 50 \text{ m}$ .

The rover is 50 m from the habitat in a straight line.




Coordinates turn a position on a map into checkable numbers.

# 5 — Changing the origin changes the numbers, not the physical world

The rover does not move if we decide to measure from the antenna instead of the habitat. Its coordinates change because zero changed.

### Same rover, new origin

Old frame: habitat=(0,0), antenna=(30,0), rover=(30,40). New origin at antenna: rover=(0,40). The rover did not move; the measurement convention changed.

---

## 6 — Reference frame versus coordinate frame

A coordinate frame is the geometrical tool used to assign coordinates. A **reference frame** is the viewpoint relative to which motion is described.

Beginner rule: **a position or velocity only has meaning when you know what it is measured relative to**.

### Rover and rescue vehicle

A rover can be stationary relative to the Martian ground but appear to move in a camera mounted on another moving vehicle. Both descriptions can be correct because the reference frames differ.

---

## 7 — Adding the third dimension: z

A flat map uses x and y. Add **z** to describe height or depth. A position `(x, y, z)` therefore contains three coordinates.

AM-01.09 · SPACE ACADEMY

**Coordinates and reference frames: say where a spacecraft actually is**

A=(0,0), B=(3,4) km.

$d = \sqrt{(3^2+4^2)}=\sqrt{25}=5$ km.

Worked example

In three dimensions, a third number describes height or depth according to the chosen convention.

# 8 — Three complete examples

## Example A — Read a position

Origin=habitat. Positive x=east, positive y=north. Rover=(12,−5) m means 12 m east and 5 m south.

## Example B — Change from A to B

A=(2,3) m; B=(7,11) m. Change in x: 7−2=5 m. Change in y: 11−3=8 m.

## Example C — New origin

Beacon=(100,20) m; rover=(130,50) m. Relative to the beacon: x=30 m, y=30 m, so rover=(30,30) m.

# 9 — Local and geographic coordinates answer different questions

x-y-z coordinates can be convenient around a base. Across a planet, geographic systems such as latitude and longitude are more suitable and follow their own conventions.

A navigation system must clearly state which coordinate system it uses. Mixing two systems can create a major error even when each number looks reasonable.

# 10 — Five questions before a coordinate calculation

1. Where is the origin?
2. Which way does each axis point?
3. What unit is used?
4. Is the model 2D or 3D?
5. Relative to which reference frame is motion described?

AM-01.09 · SPACE ACADEMY

# Coordinates and reference frames: say where a spacecraft actually is

Always check units, assumptions and the domain of validity.

A model is a tool: it does not replace testing and qualification.

Limits and verification

A coordinate without its frame convention is incomplete information.

## Exercises and answers

### Exercise 1

Positive x=east, positive y=north. Translate (−4,9) m.

Answer: 4 m west and 9 m north of the origin.

### Exercise 2

A=(1,2), B=(6,5). Find changes in x and y.

Answer: Δx=5, Δy=3. The symbol Δ is read “delta” and here means “change in”.

### Exercise 3

Why can a rover's coordinates change while it does not move?

Answer: because the origin or axes can be changed. The numbers change, not the physical position.

## Primary and technical sources

- NASA/JPL NAIF — reference frames and geometry
- NIST SP 811 — SI units