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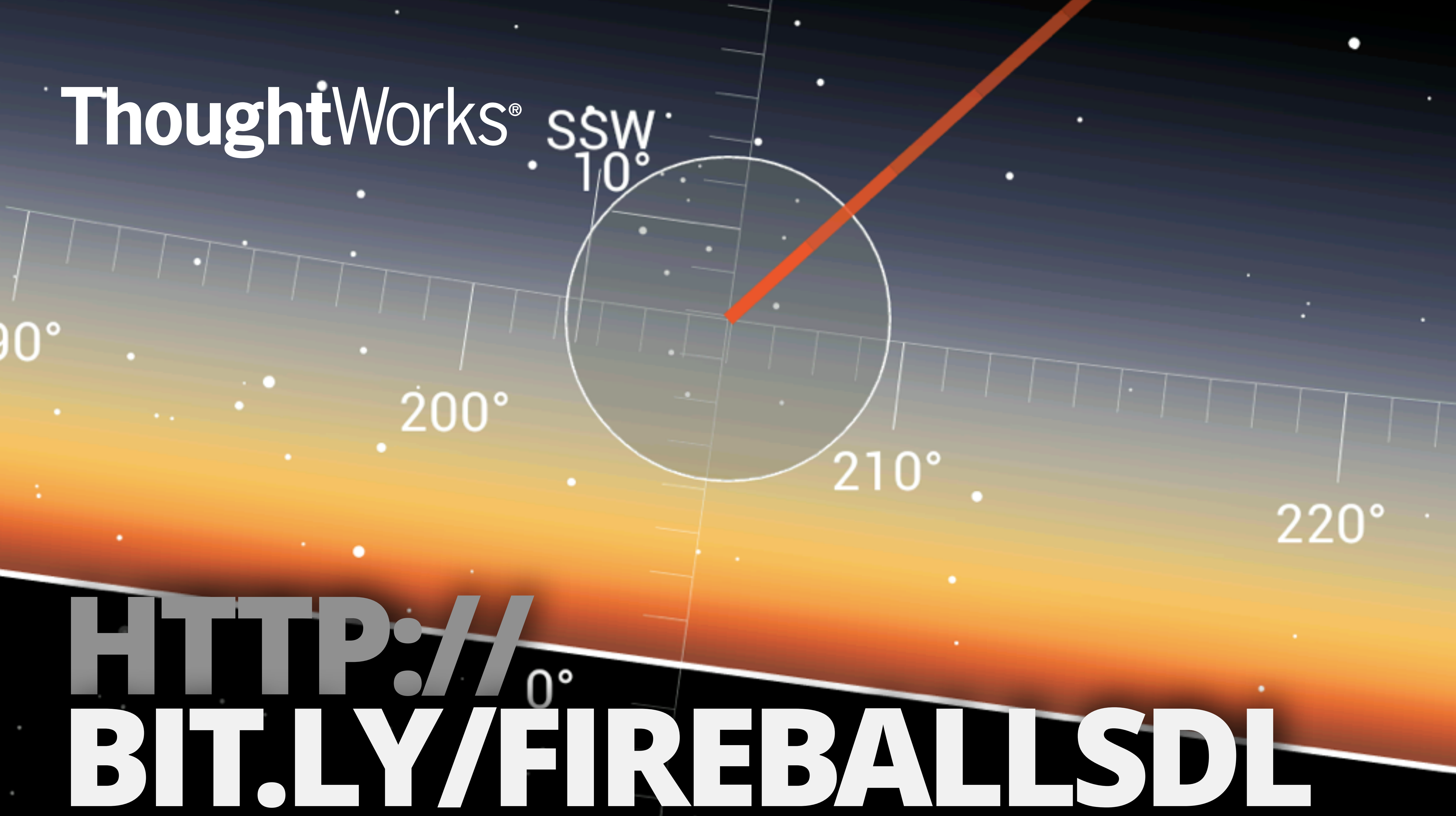
bespoke AR for mobiles

SEEING STARS

Using technology to deliver an engaging app to capture meteorite sightings, on Android and iOS



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HTTP:// BIT.LY/FIREBALLSDL

Or search App Store or Google Play for “Fireballs in the Sky”

HELLO

DAVID COLLS
Maths nerd
@davidcolls
AR MATHS

BRAD WARD
Developer

IOS

NATHAN JONES
Developer
@the_nathanjones
ANDROID

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FIVE* WHYS

** Actual number may vary*

1. WHY NATIVE?

To describe a fireball

Words & numbers fall short, so animated recreations were MVP.

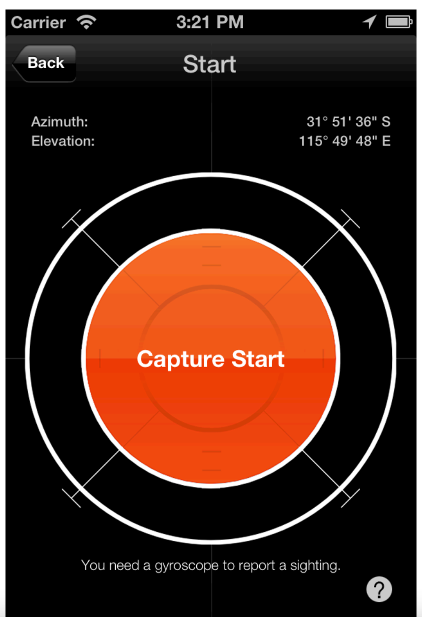
With particle systems

Demanded performance beyond the reach of mobile web for the majority of devices.

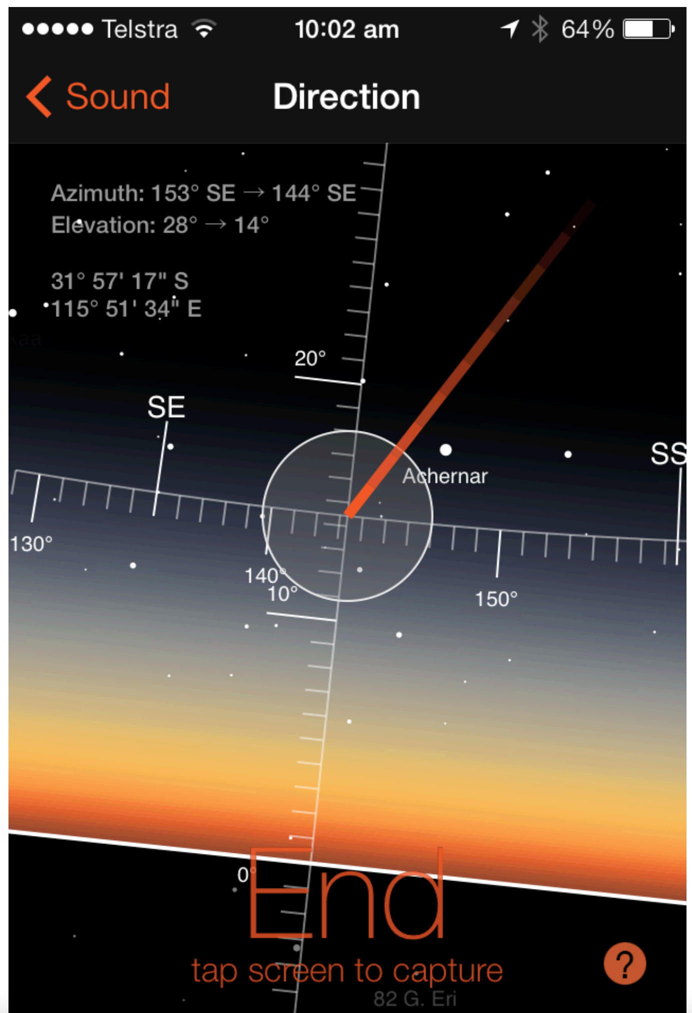
Meant 2 native apps

Developed in parallel.

2. WHY AUGMENTED REALITY?



Release 1



Release 2

AR not MVP,
but *delightful*

And improved reporting

Option for
Release 1

Implemented in
Release 2

3. WHY BESPOKE AR?

A unique context

No desire to license technology

Based on sensors not camera image

Camera view just black at night

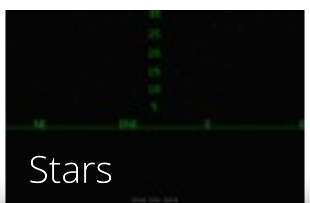
Very simple interaction

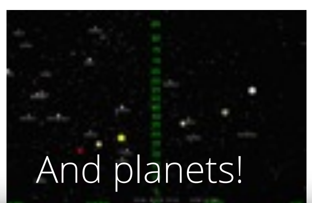
Google Sky only Android

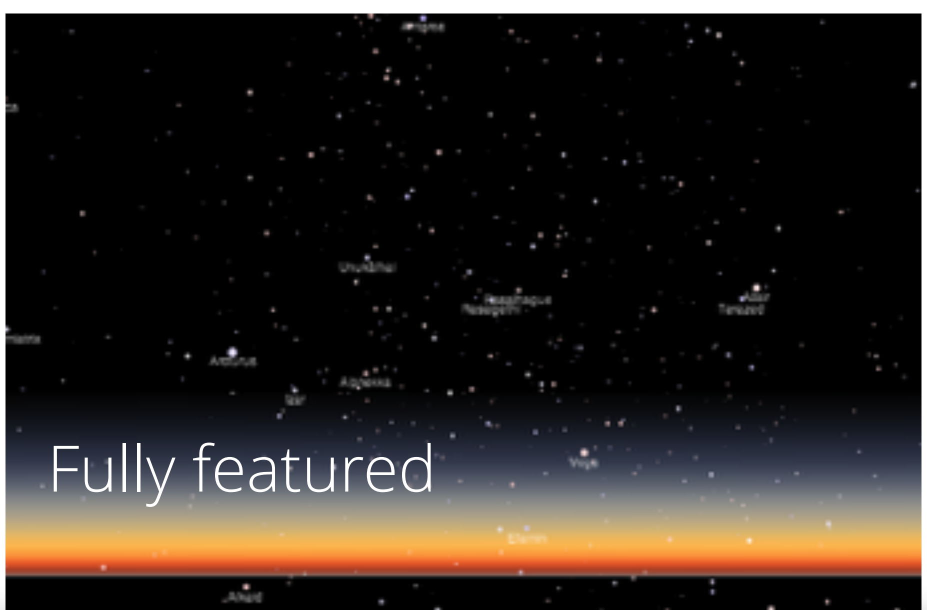
Google Sky won’t subordinate

And we had a Processing prototype

4. WHY PROTOTYPE IN PROCESSING?







Fastest way to start

Dave knew Processing (visualisation IDE)

Rapidly iterate and demonstrate we could do star maps (highest risk)

No dependencies

And finish

Porting together would be low risk

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AR MATHS*

* Guaranteed to contain NO equations

APPROACH

Where are the stars?

How do we draw this (in a virtual window)?

APPROACH

Where are the stars?

Where in the universe?

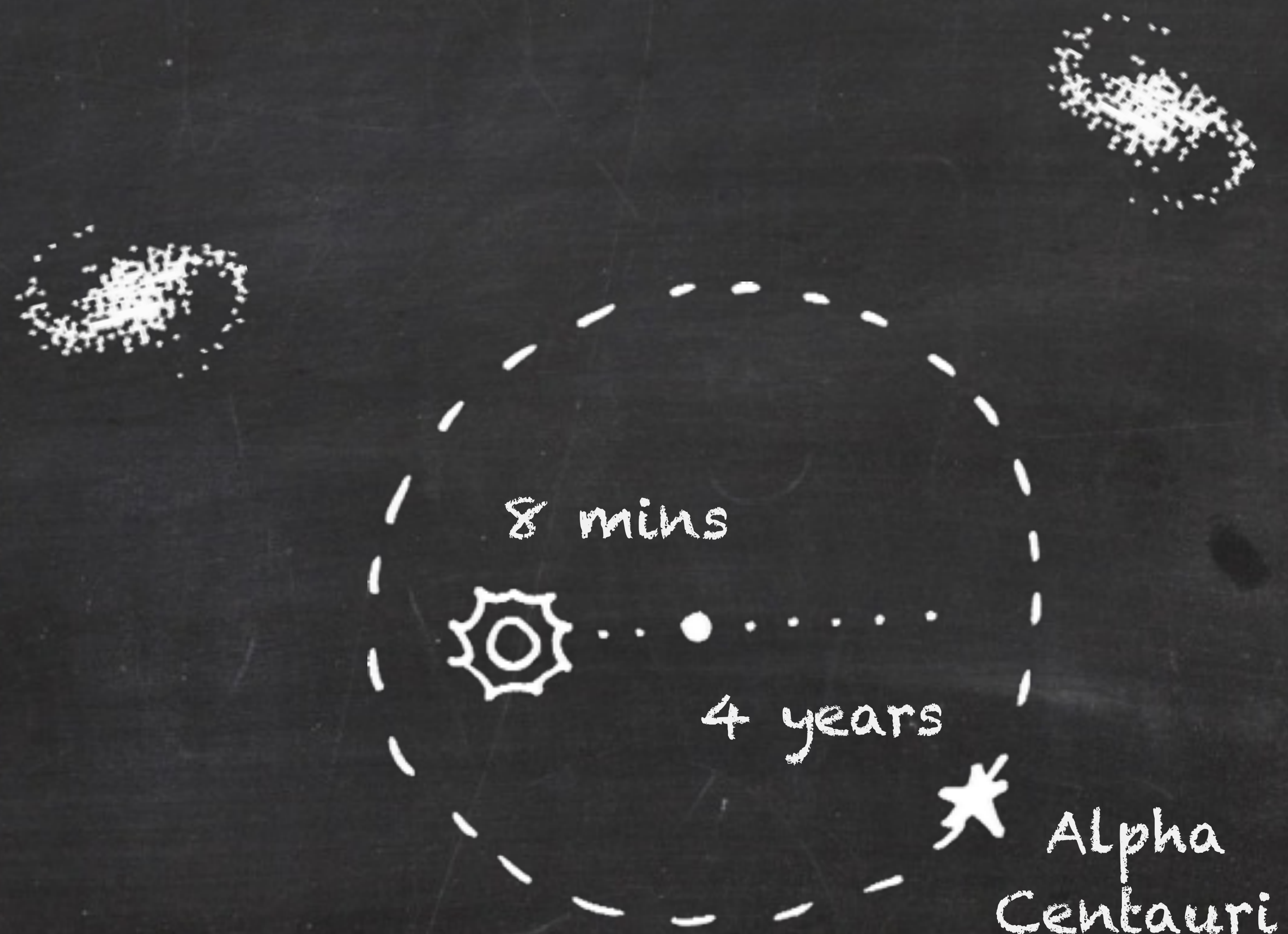
Where in the sky?

How do we draw this (in a virtual window)?

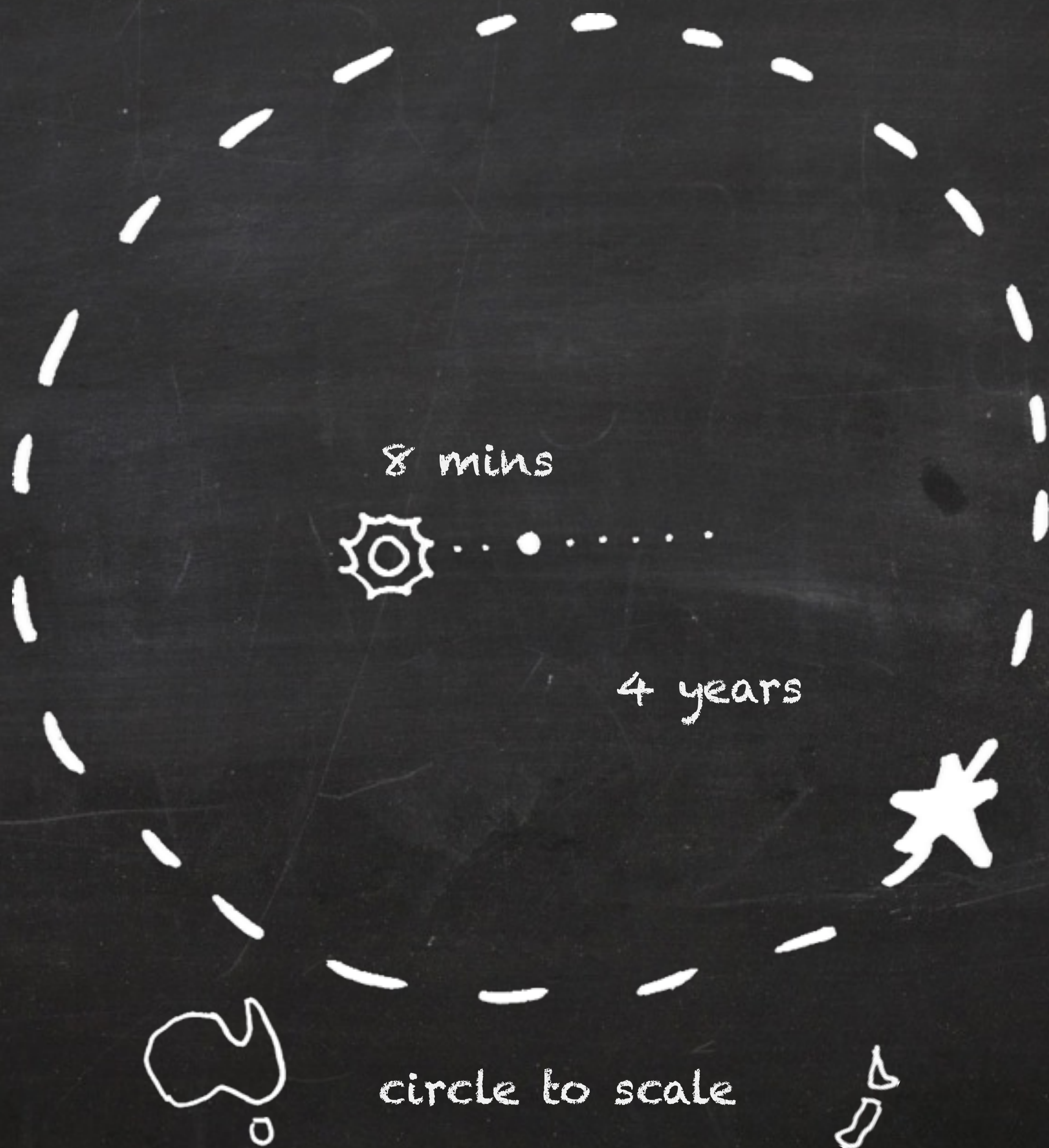
Where are you looking?

Where are you standing?

WHERE IN THE UNIVERSE?



WHERE IN THE UNIVERSE?

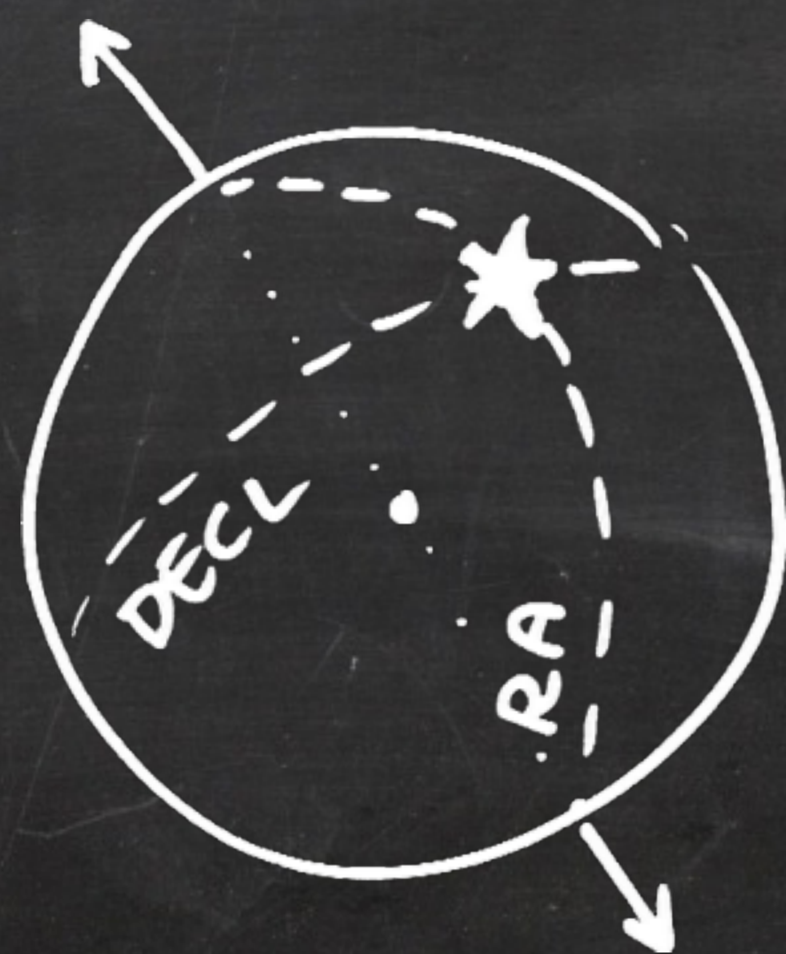


WHERE ARE THE STARS?

Infinitely distant

“Fixed Stars”

HYG Database



Celestial sphere

WHERE ARE THE STARS?

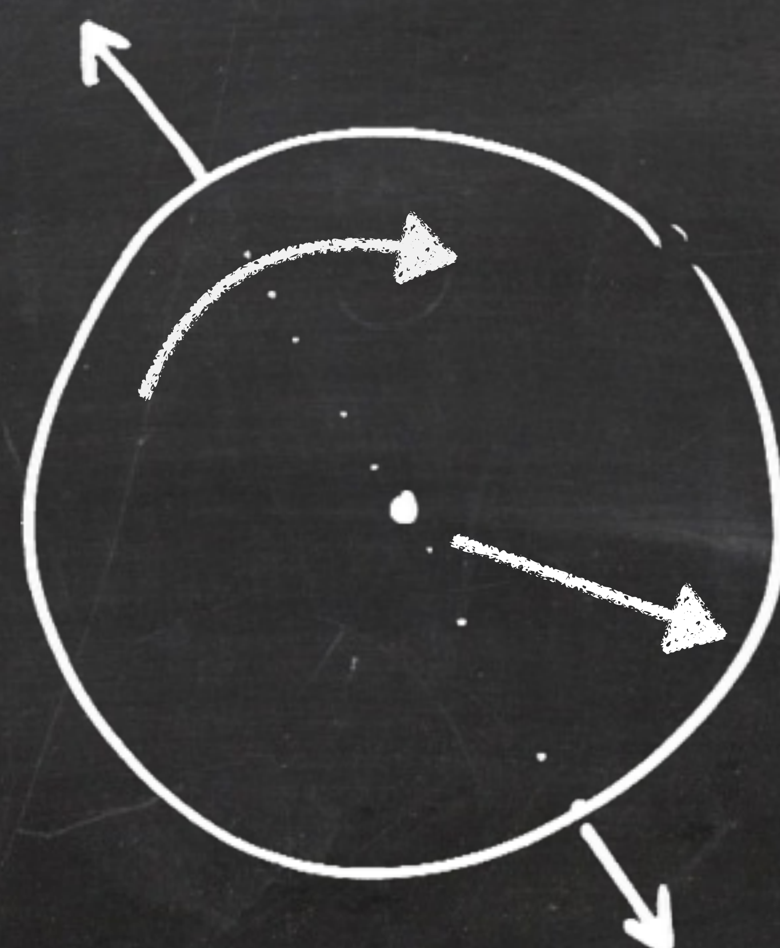
Infinitely distant

"Fixed Stars"

DB

HYG Database

How do the stars look from the earth's surface?



Celestial sphere

How much has the sphere rotated?

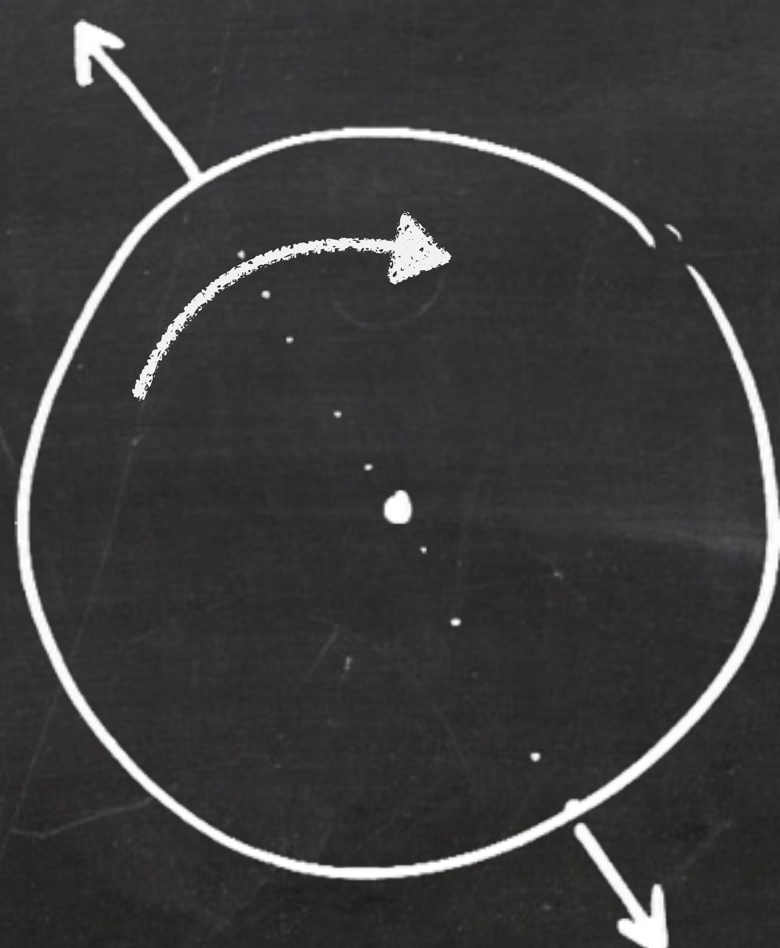
What part of the sphere is directly overhead?

WHERE IN THE SKY?

Time
+ Date

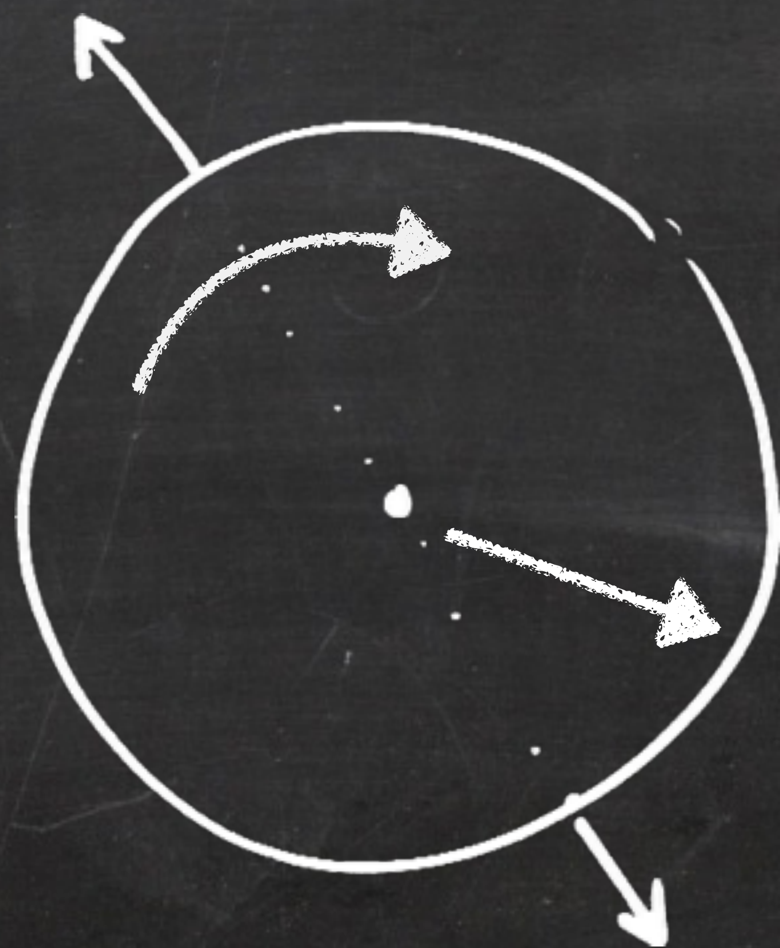
Siderial Time
+ Longitude

LOCAL
SIDERIAL
TIME



Celestial
sphere

WHERE IN THE SKY?



Celestial sphere

Time
+ Date

Siderial Time
+ Longitude

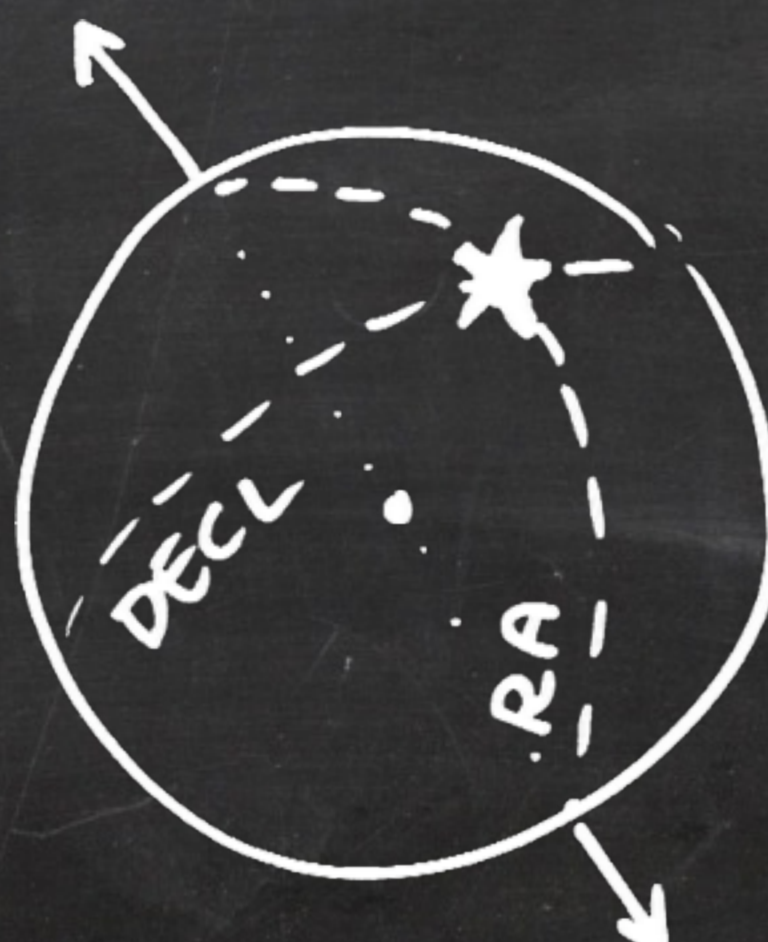
LOCAL SIDERIAL TIME

LATITUDE

WHERE IN THE SKY?

Azimuth
Elevation

Terrestrial
observer



Celestial
sphere

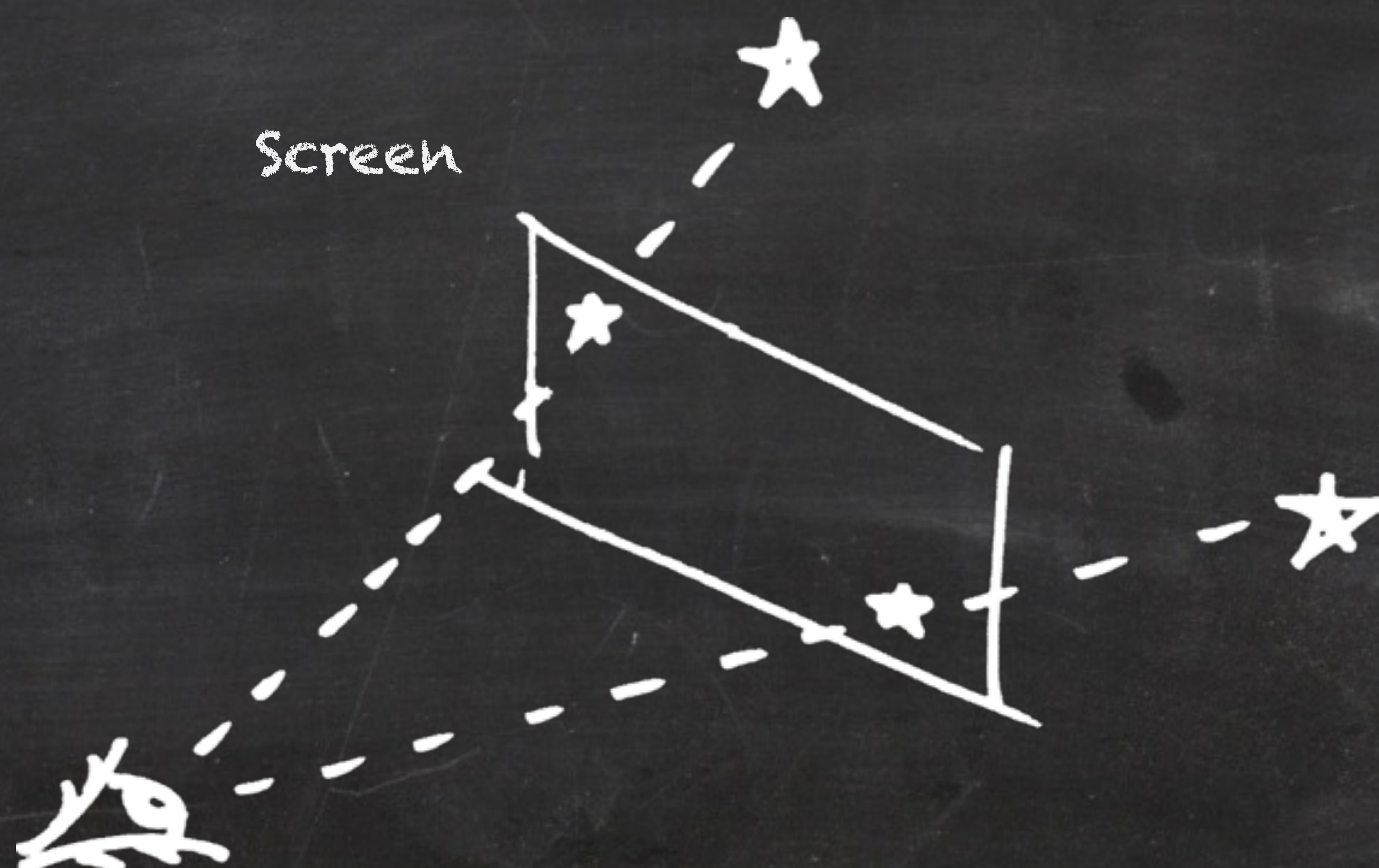
Time
+ Date

Siderial Time
+ Longitude

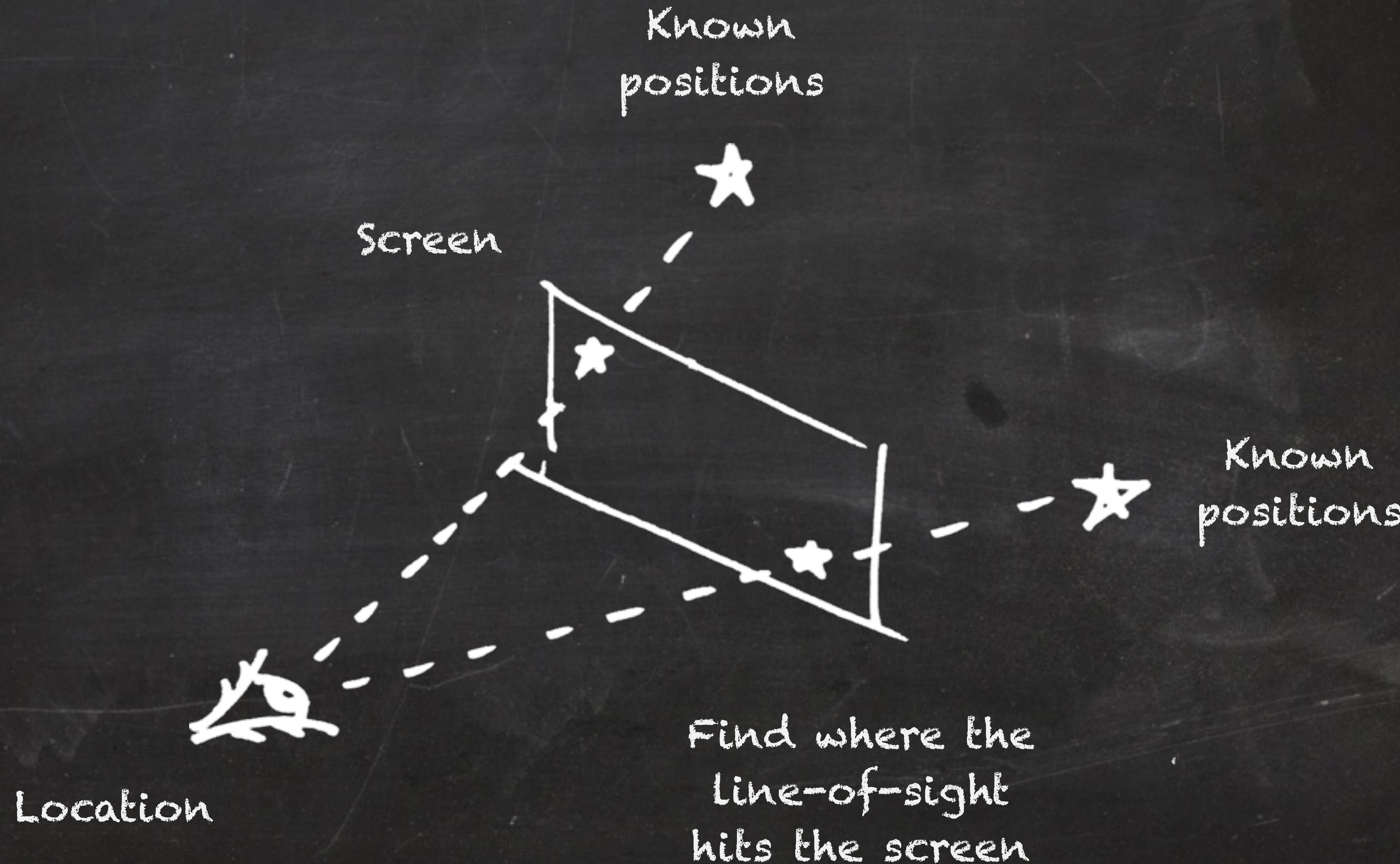
LOCAL
SIDERIAL
TIME

LATITUDE

DRAWING IN A VIRTUAL WINDOW

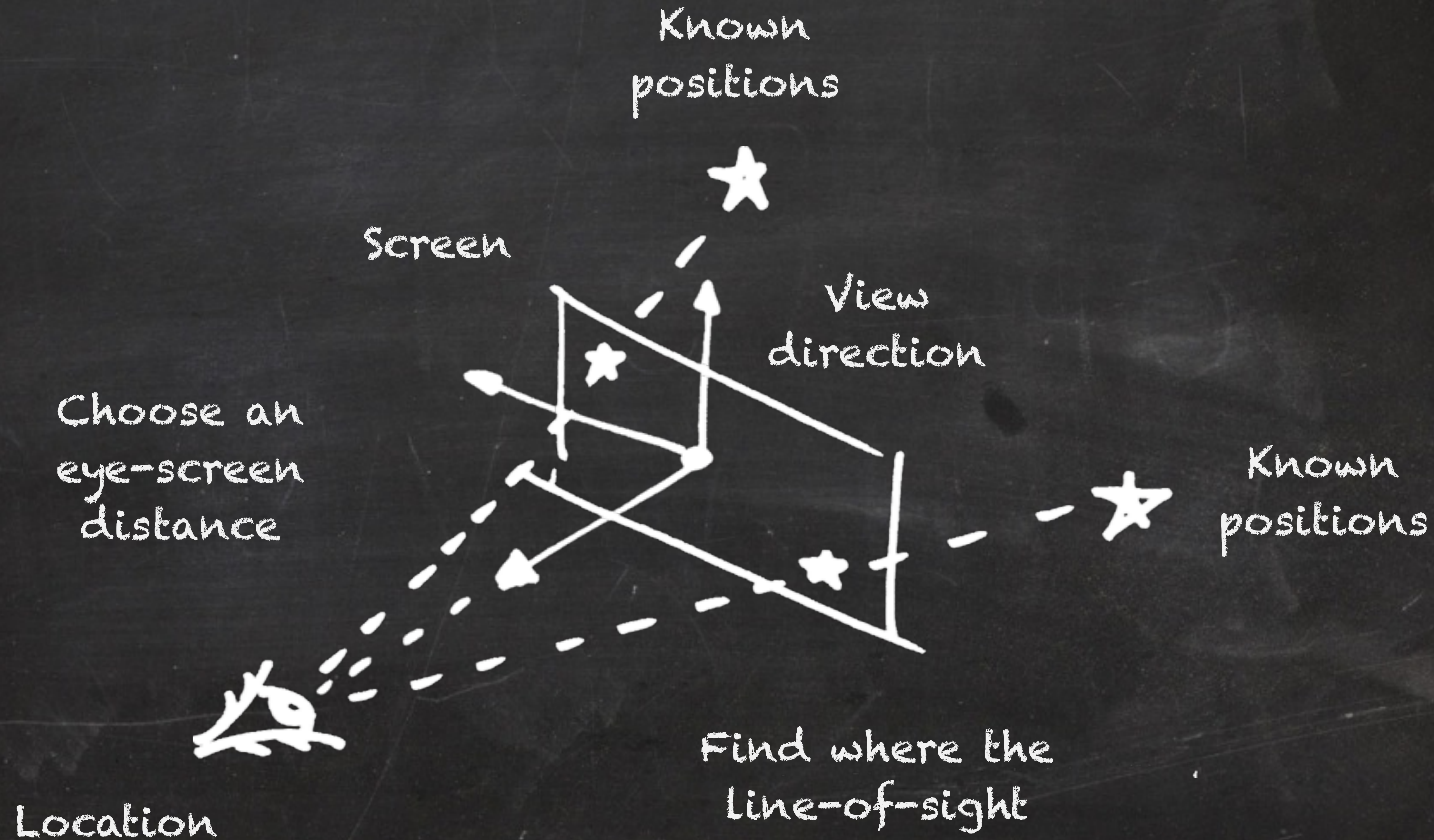


DRAWING IN A VIRTUAL WINDOW



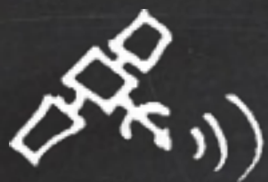
Perspective Projection

DRAWING IN A VIRTUAL WINDOW



Perspective Projection

WHERE ARE YOU STANDING?



GPS satellites

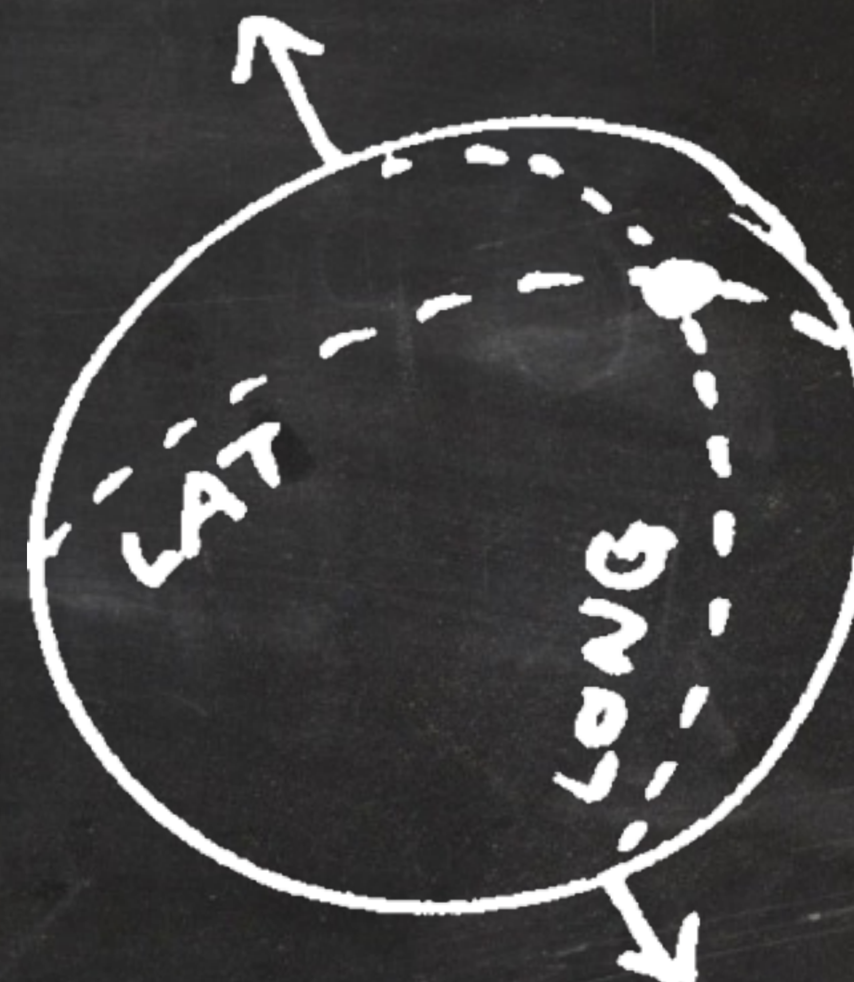
Cell towers

WiFi access points

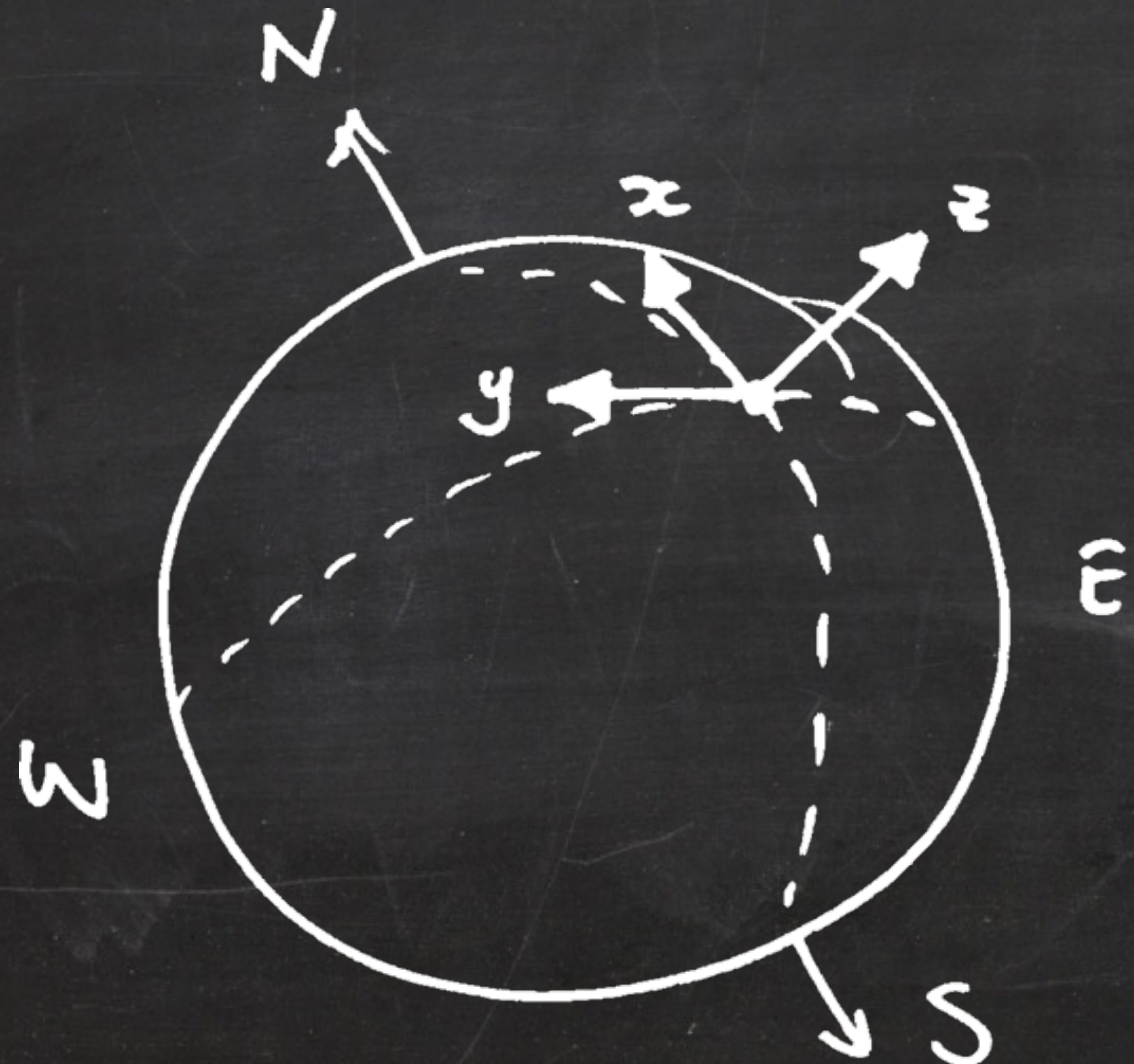
API

CLLocationManager

LocationManager



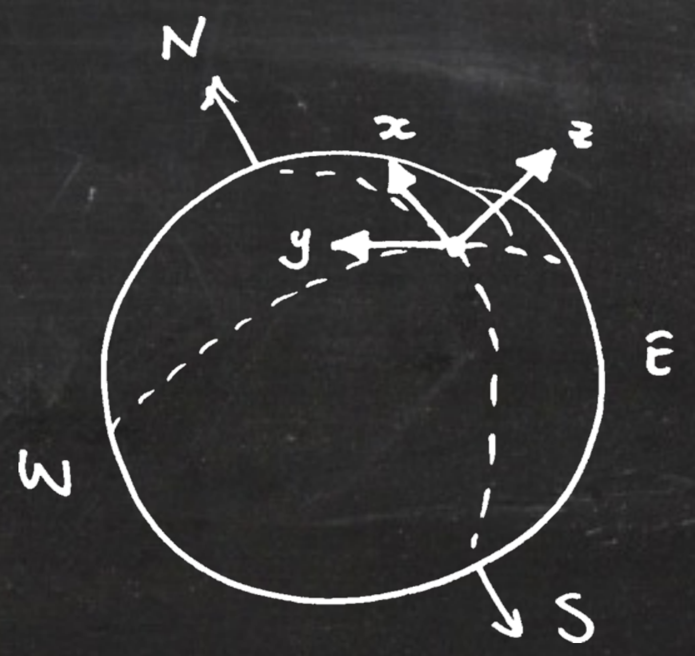
DEFINES LOCAL REFERENCE FRAME



X - North
Y - West
Z - Up

X - East
Y - North
Z - Up

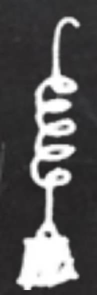
WHERE ARE YOU LOOKING?



...with respect to local reference frame

WHERE ARE YOU LOOKING?

Magneto-
meters



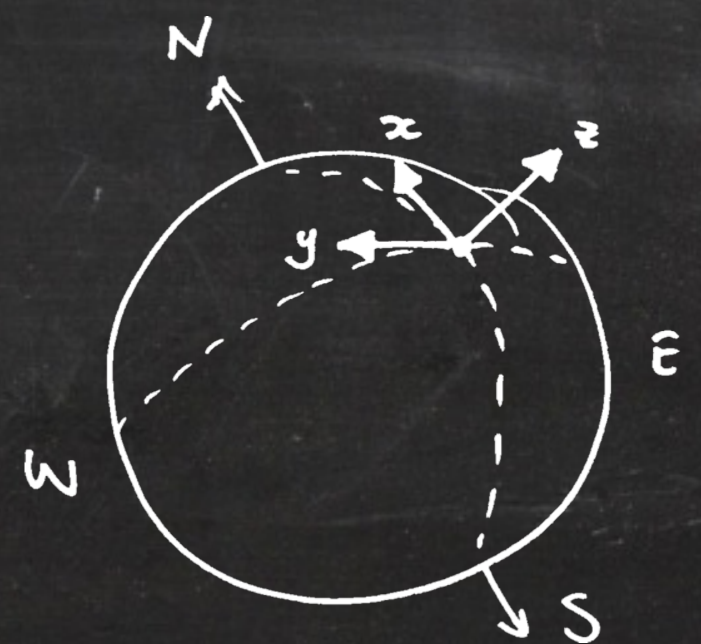
Accelero-
meters

Gyroscopes

API

SensorManager
Register for updates & getOrientation()
WindowManager
Device default orientation

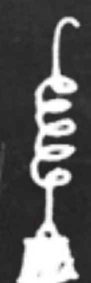
CLLocationManager
For heading
CMMotionManager
RefFrameXTrue NorthZVertical



...with respect to local reference frame

WHERE ARE YOU LOOKING?

Magneto-
meters



Accelero-
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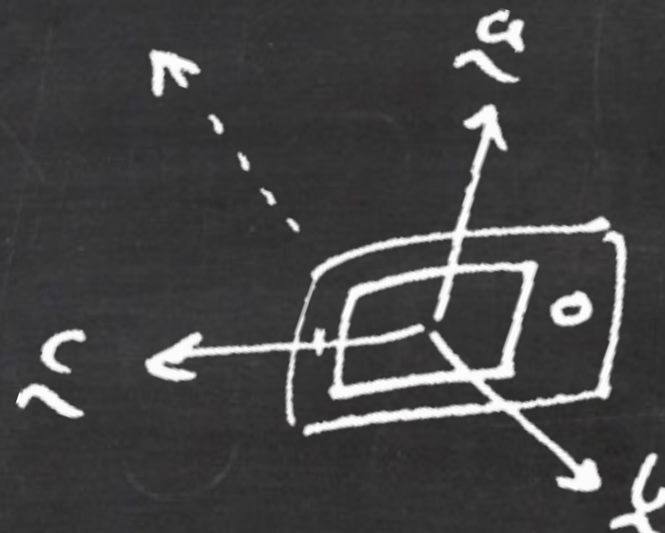
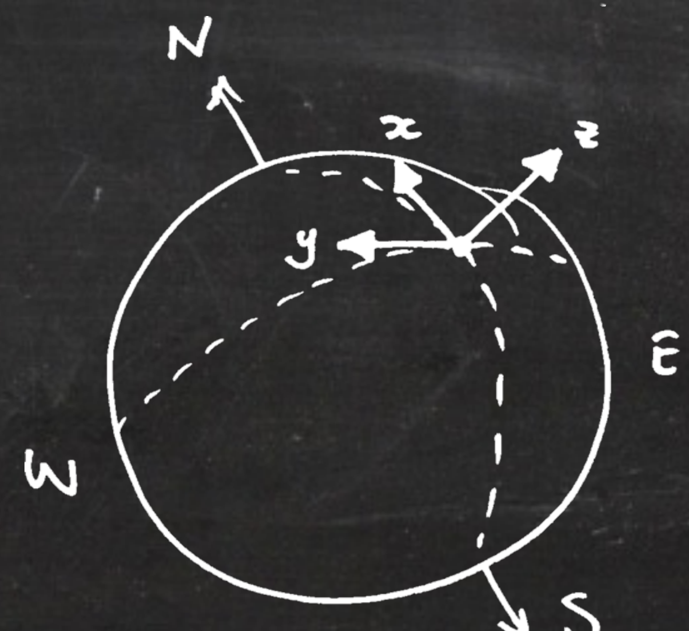


$$\begin{bmatrix} a_x & b_x & c_x \\ a_y & b_y & c_y \\ a_z & b_z & c_z \end{bmatrix}$$

Device rotation matrix...



...with respect to local reference frame

WHERE ARE YOU LOOKING?

Magneto-
meters

Accelero-
meters

Gyroscopes

API

SensorManager
Register for
updates &
getOrientation()
WindowManager
Device default
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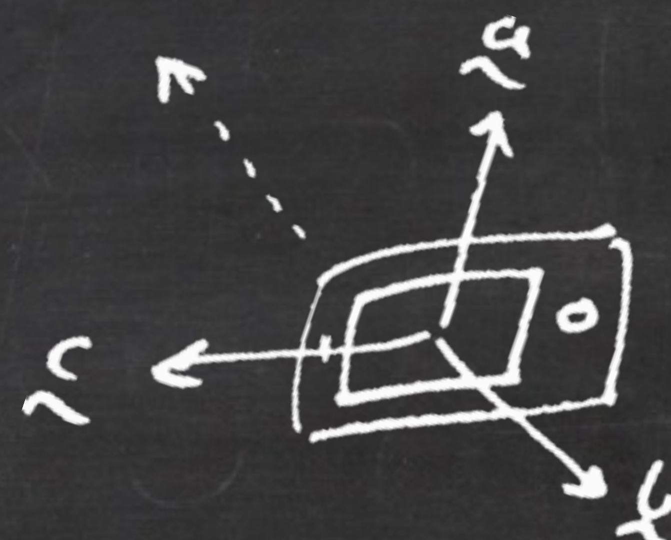
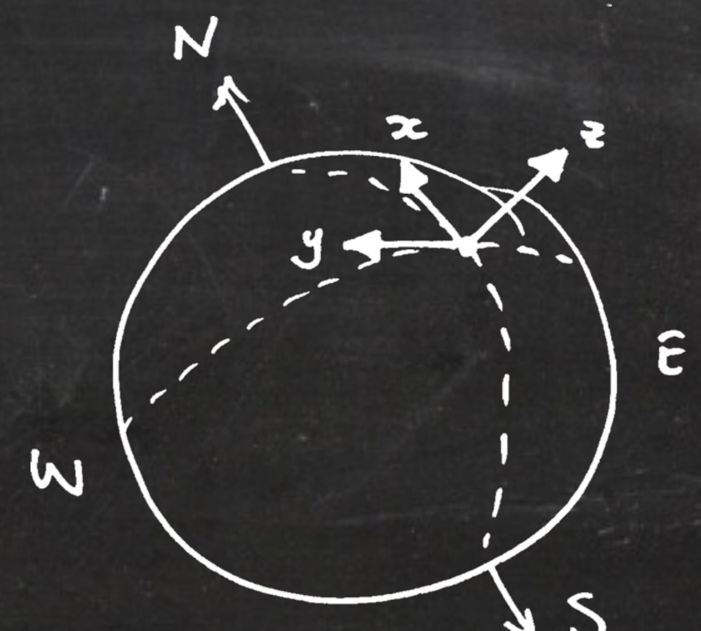


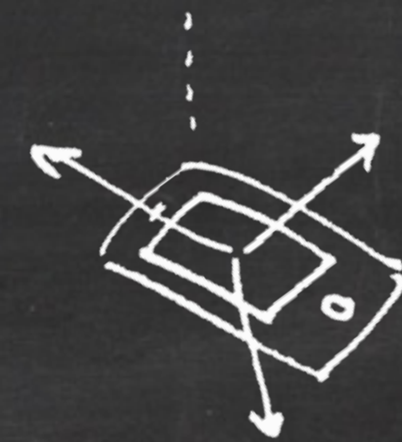
$$\begin{bmatrix} a_x & b_x & c_x \\ a_y & b_y & c_y \\ a_z & b_z & c_z \end{bmatrix}$$

Device
rotation
matrix...



...with respect
to local
reference
frame

WHERE ARE YOU LOOKING?



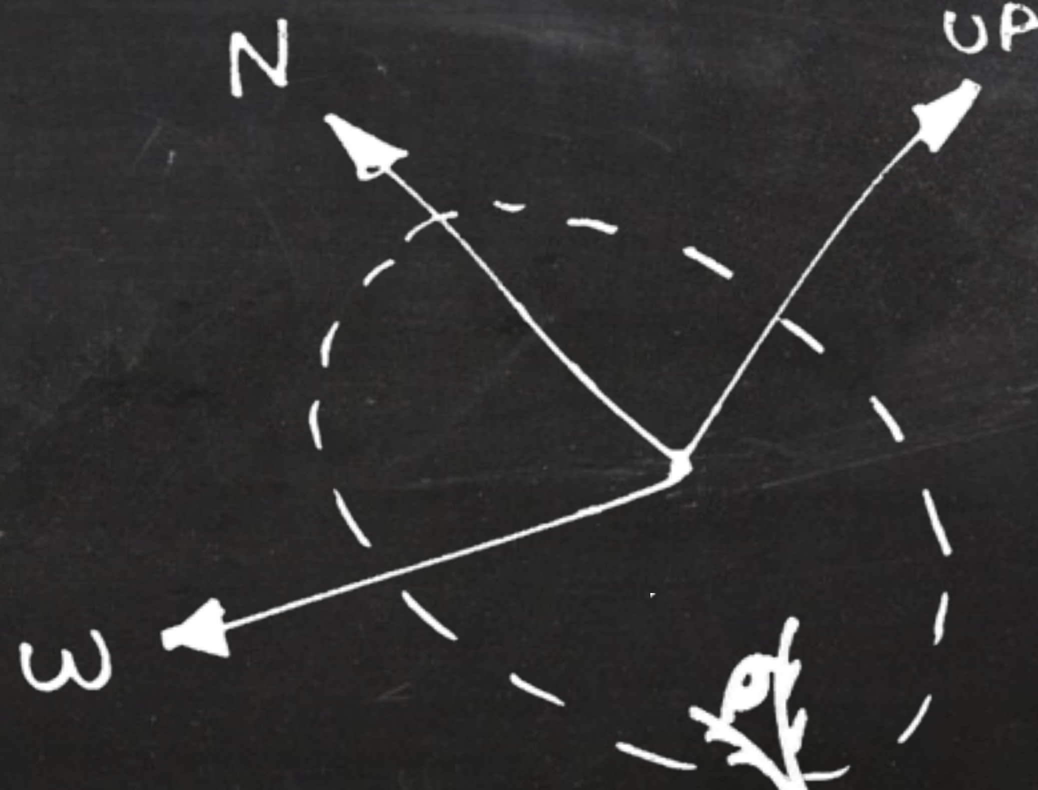
$$\begin{bmatrix} a_x & b_x & c_x \\ a_y & b_y & c_y \\ a_z & b_z & c_z \end{bmatrix}$$

Azimuth

Elevation

Tilt

Obtained from device rotation matrix



REVIEW

Once per universe*

[RA & DECL]
(Fixed stars)

Where in the universe?

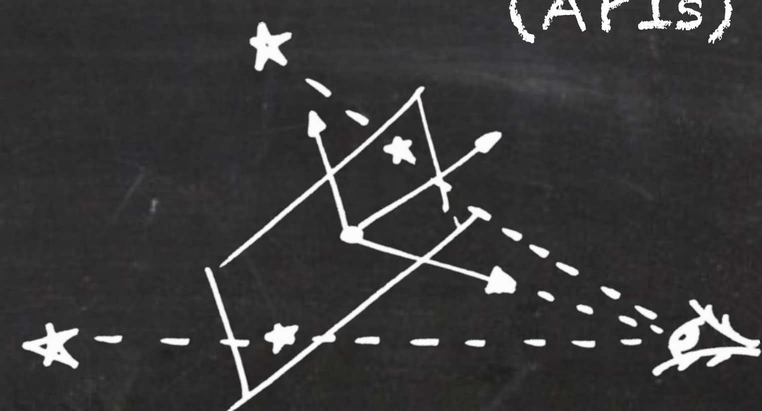
Once per session

[Azimuth & Elevation]
(LST & Lat)

Where in the sky?

Every frame

Device rotation matrix
(APIs)

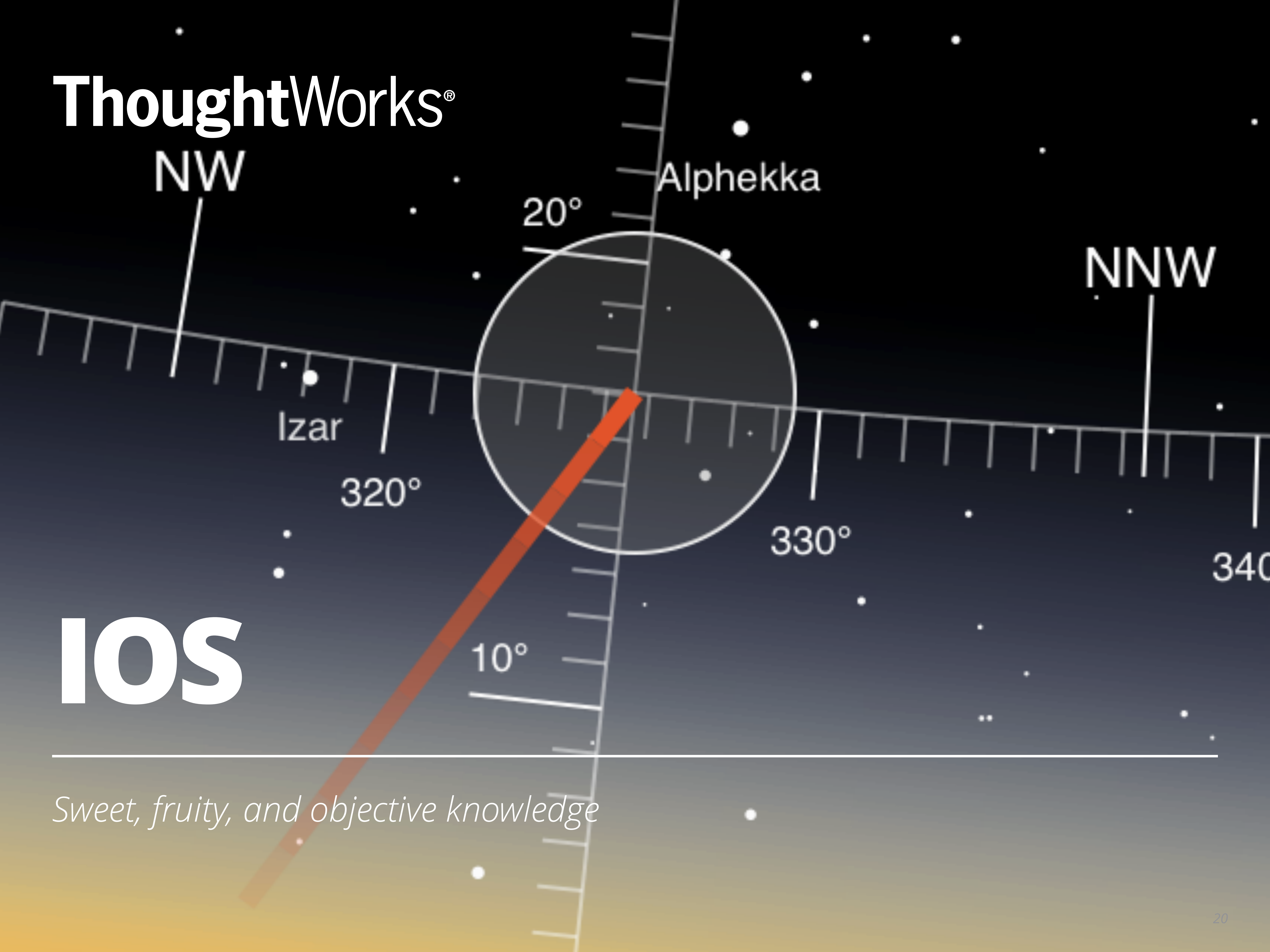


Where are you looking?

Once per session

Device location
(APIs)

Where are you standing?



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IOS

Sweet, fruity, and objective knowledge

Core Location & CoreMotion

CLLocationManager latitude - longitude

CMMotionManager azimuth - elevation - tilt

- Using `CMAttitudeReferenceFrameXTrueNorthZVertical` reference frame
- The API-provided `pitch`, `roll` and `yaw` were not used (pitch and yaw don't compensate for roll). Used `deviceMotion.attitude.rotationMatrix` directly instead.
- Reference frame 'drifts' over time, periodic resets resolve this.

IOS INGREDIENTS

Accelerate/vecLib library hardware-accelerated vector maths

- vecLib uses the *Advanced SIMD* instruction set implemented by NEON on ARMv7 devices (iPhone 4 and above, iOS 4.3 and above), with fallbacks for older devices
- 2-10x performance bump over standard

~~Objective~~ **C**

- Avoided overhead of classes/GC in calculation code
- Work well with Accelerate library's C interface
- Rendering code is Objective-C

IOS INGREDIENTS

CoreGraphics

- CPU-based 2d rendering
- Minimal development effort with reasonable flexibility
- Was an expected (and realised) performance bottleneck
    - OpenGLES would provide dramatically improved performance, at higher development cost.
- Final performance was good on iPhone5 devices

Graceful degradation was added for iPhone4 - stars are rendered as squares rather than circles, star labels are not rendered and the horizon image is thinner.

IOS IMPLEMENTATION

So many options to improve performance…

- ☐ Optimise use of Accelerate library via bulk calculations
- ☐ OpenGLES (eg. Cocos2D or SpriteKit) for rendering
- ☐ Multithreading
- ☐ Full GPU implementation of star-positioning calculations

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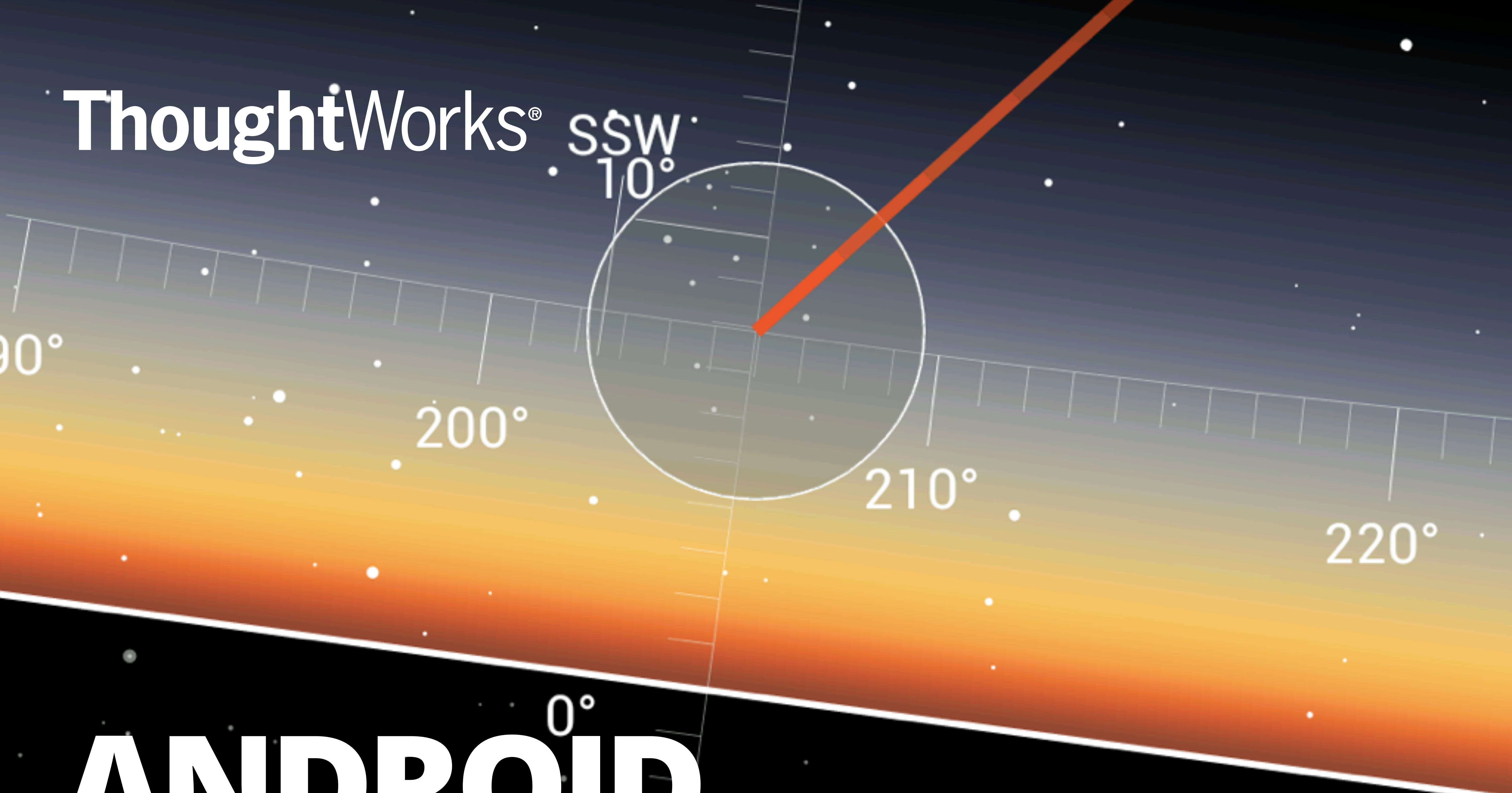


ANDROID

Developing for the bot with the lot

Which API?

`SensorManager` is the home for all sensors in Android

Lots of change in this area of the API

Reference examples use deprecated `ORIENTATION_SENSOR`

Hand-rolled sensor fusion of accelerometer and compass

Take a look at the `ROTATION_VECTOR` Sensor

Adjust resulting vector for current and default orientation

How do I draw them?

We use a regular `SurfaceView`

We use a `Timer` targeting 60FPS instead of an explicit thread

Draw on a regular 2D `Canvas`

Not hardware accelerated

Code split into set of renderers

Toggled FPS renderer for performance testing

Room for improvement

Coding Style

Optimised vector math libraries not as mature

Embrace some functional paradigms, separate state and behaviour

Multi-threading is an option

Beware the garbage collector

Profile all the things, these are limited resources

Many ways to skin a cat with vastly different performance

ANDROID - HERE BE DRAGONS

Fragmentation exists

Expect it and deal with it

Eligible for installation on 3606 devices

Pick a baseline and work out what you are in for

Don’t expect the API to be consistent

Get some real devices

Lowest and highest target OS versions

Lowest and highest screen sizes - resolution and physical size

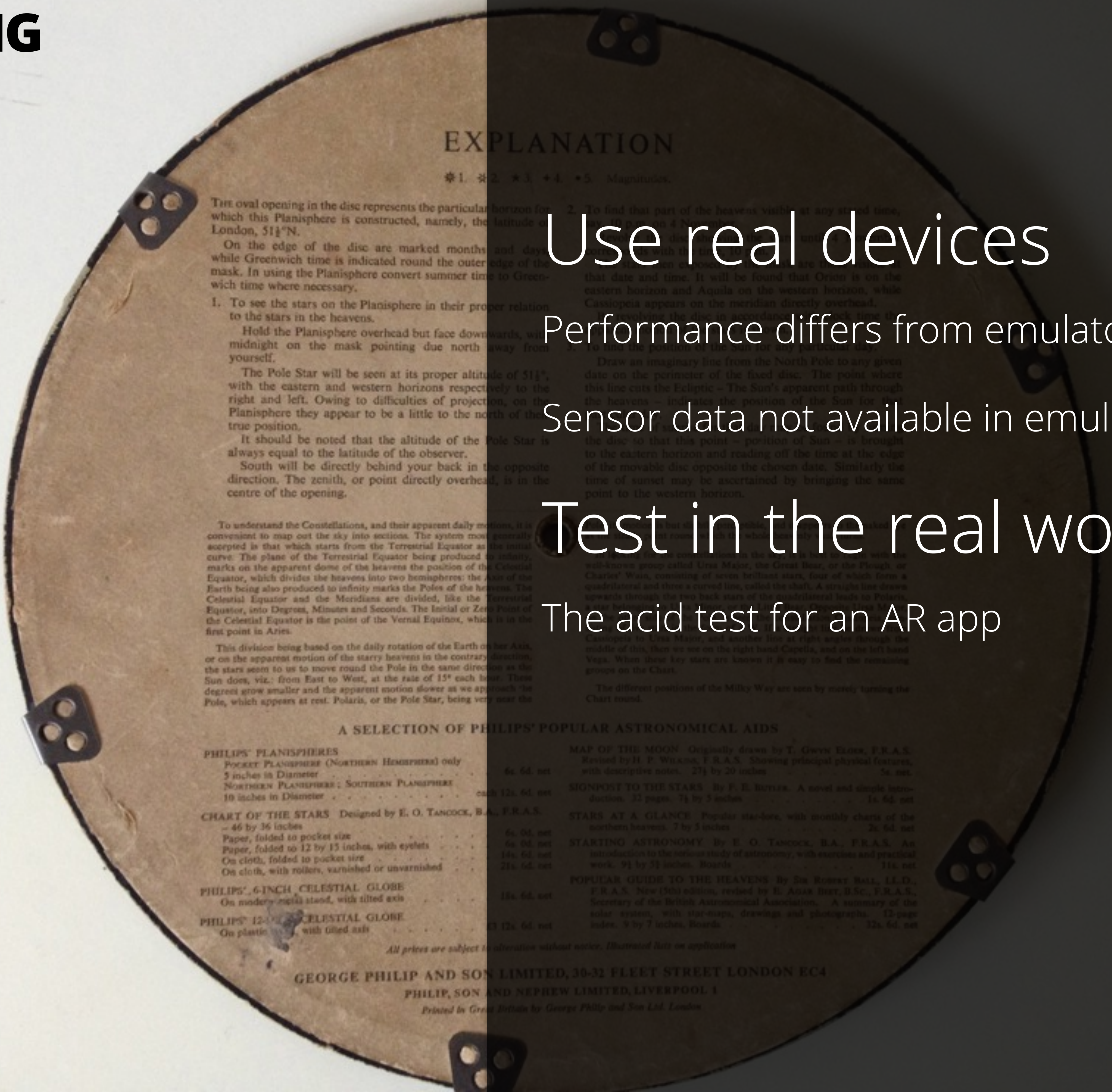
Lowest performance - slow single-core phones

Fall back to emulator only for sanity check on look and feel

BUILDING APPS

On both Android and iOS

TESTING



Use real devices

Performance differs from emulators

Sensor data not available in emulators

Test in the real world

The acid test for an AR app

LOCATION

Think about usage

No wifi or cell towers in the outback

Don’t block the user

While you find their location

Enough is enough

Know the required accuracy,
and stop when you have it

Stop wasting their battery (Android)

Turn off location services on app hide

DEVICE ROTATION

Differences in APIs

Android vs iOS

Frame of reference

True North or Magnetic North?

(Does it matter in Perth?)

Smoothing

How to filter noise while preserving a responsive signal

THANK YOU

For questions or suggestions:

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