MapKit 3D

Running Xcode 16.3+ and visionOS 2.3+?

If not, download it *NOW* and Start Xcode!

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Cocoaheads Aachen, May 22, 2025

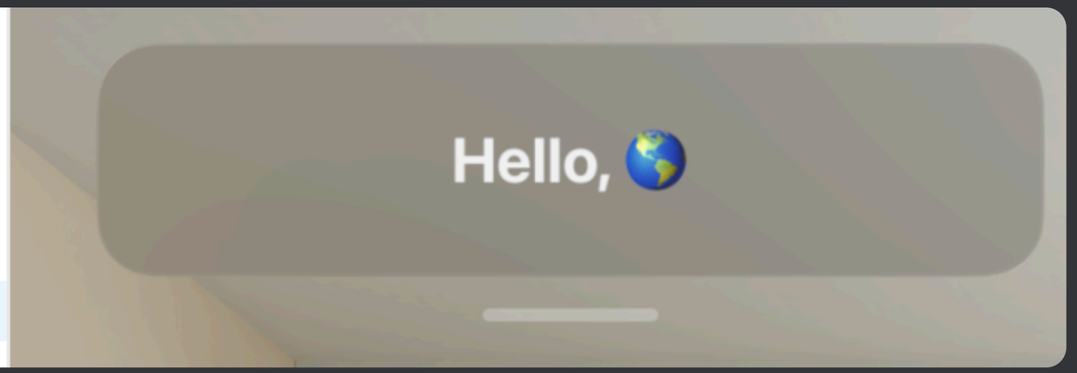
MapKit3D_Starter.zip

- We'll do the App without Reality Composer Pro!
- A 2D Map will be shown next to our 3D Globe
- We'll stick as much possible to the MapKit Models
- We won't build an exact replica of MapKit for SwiftUI
- I might open source this as a framework after WWDC...

Preview

Preview **`ContentView`** to make sure it compiles and works.

```
struct ContentView: View {
    var body: some View {
        Text("Hello, 🌎").font(.extraLargeTitle)
    }
}
```

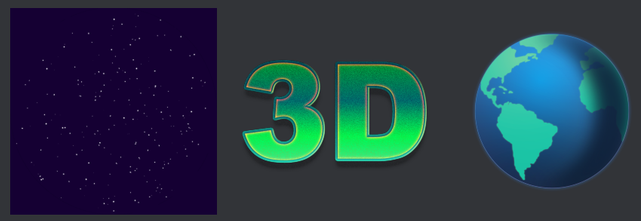


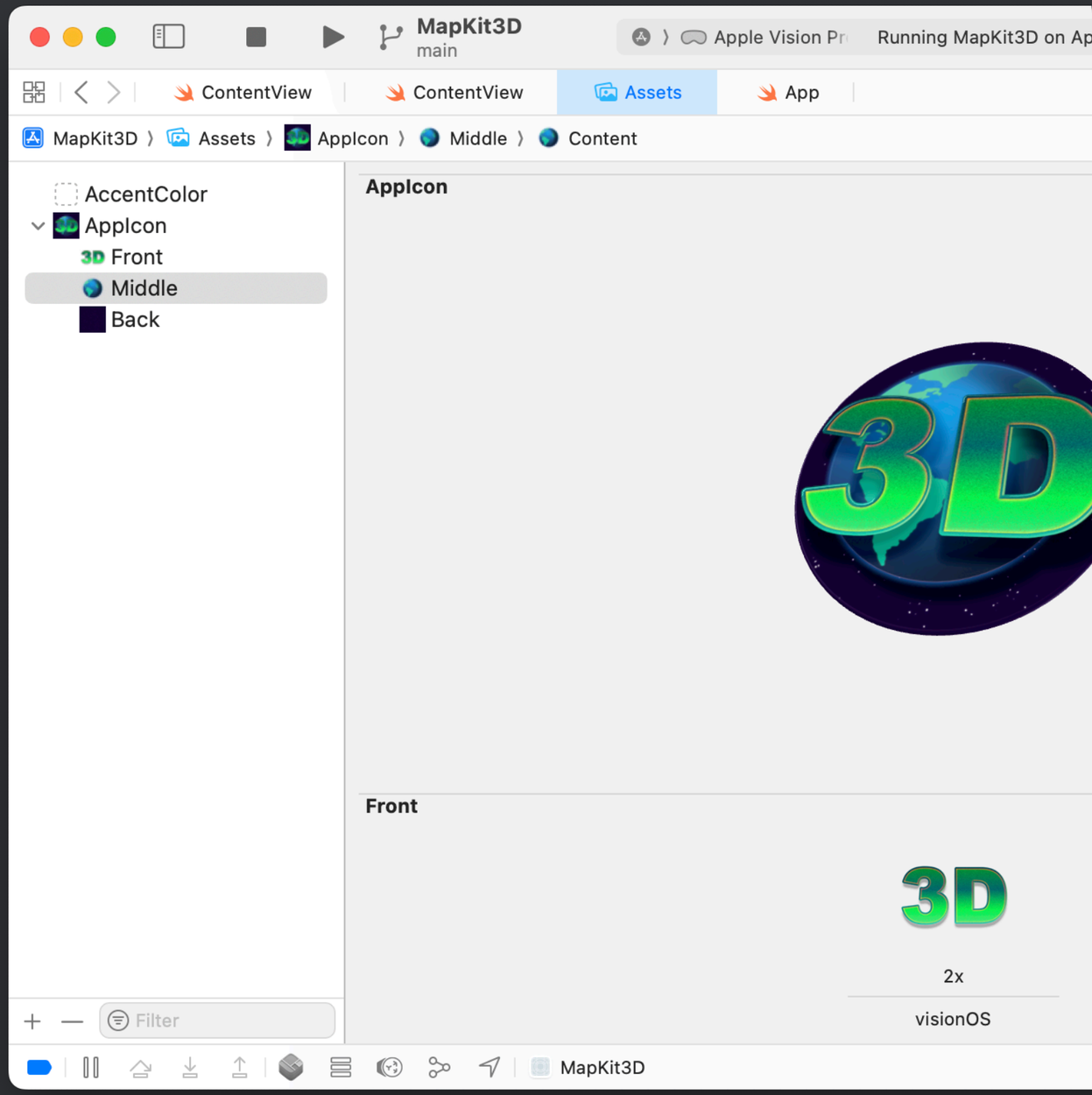
- See how it has a beautiful glass background in Preview!

Run

- Run in in the Simulator to make sure as well.
- Learn the basics of the Simulator
  - **Show Home with ⇧ ⌘ H** — *Oh, a boring/empty Icon!*
  - Move around and use **`Debug > Show Gaze Target`**

Icon

- `AppIcon` in `Assets`.
- Use **`middle`** and **`back`** (and **`front`**?)
- 



Replace the body of ContentView

```
import MapKit

var body: some View {
    Map()
}
```

Look at the bottom left corner

Apple didn't give MapKit much love in visionOS

No glass anymore in the Preview!

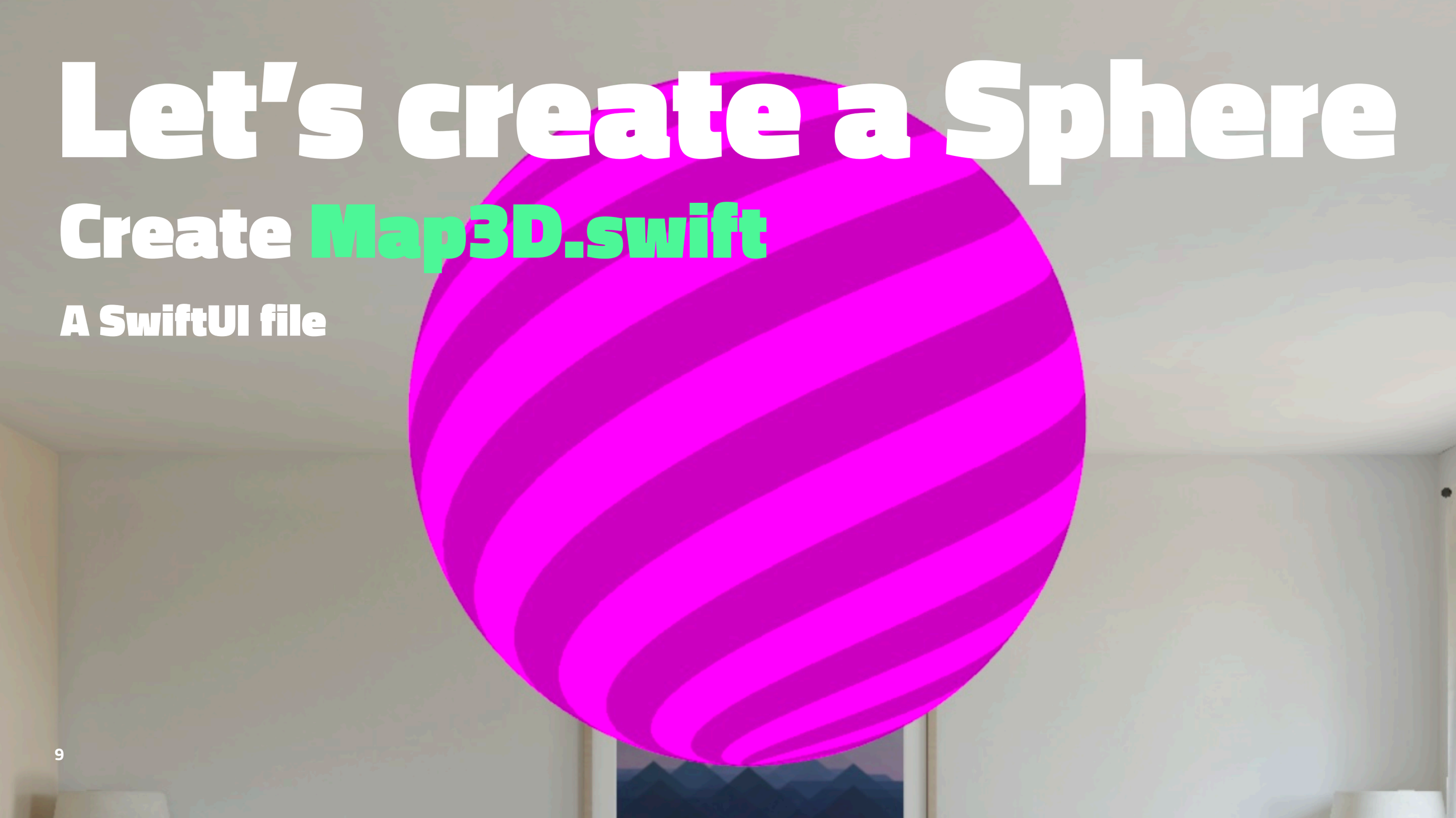
Fix it old school

```
#Preview(windowStyle: .automatic) {
    ContentView()
        .glassBackgroundEffect()
}
```

Let's create a Sphere

Create Map3D.swift

A SwiftUI file



```swift
import RealityKit

@State private var globe: ModelEntity!
private let radius: Float = 0.4

var body: some View { realityView }

private var realityView: some View {
  RealityView { content in
    await setup()
    content.add(globe)
  }
}
private func setup() async {
  globe = ModelEntity(mesh: .generateSphere(radius: radius))
}
```

Add a Preview

```
#Preview(windowStyle: .volumetric) {
    Map3D()
}
```

- Because if you run the previous code, nothing will happen anyways
- Time to open that 3D Globe when the app starts!

Auto-open it on start

```
struct MapKit3D: App {
    var body: some Scene {
        WindowGroup(id: "a") { ContentView() }
        WindowGroup(id: "g") { Map3D() }.windowStyle(.volumetric) }
    }
}
struct ContentView: View {
    @Environment(\.openWindow) private var openWindow

    var body: some View { Map().onAppear { openWindow(id: "g") }
```

- We'll use the **id a** in a minute…


London
Guildford
Brighton
Amsterdam
The Hague
Rotterdam
Eindhoven
Antwerp
Ghent
Brussels
Lille
Amiens
Le Havre
Rouen
Caen
Reims
Paris
Le Mans
Orléans
Angers
Tours
Dijon
Besançon
Basel
Zürich
Maps
Budapest
Kraków
Olsztyn
Kielce
Bratislava
Gdańsk
Gdynia

Open it on the side

```
...
        .windowStyle(.volumetric)
        .defaultWindowPlacement { _, ctx in
            guard let content = ctx.windows.first(where: {
                $0.id == "a" }
            ) else {
                return WindowPlacement(nil)
            }
            return WindowPlacement(.leading(content))
        }
    }
}
```


Schleswig-Holstein Wadden Sea National Park
Lower Saxony Wadden Sea National Park
Rostock
Lübeck
Hamburg
Gdynia
Gdańsk
Szczecin
Groningen
Bremen
Bydgoszcz
Toruń
Gorzów Wielkopolski
Berlin
NETHERLANDS
Amsterdam
Hannover
Braunschweig
Magdeburg
Poznań
POLAND
The Hague
Rotterdam
Münster
Bielefeld
Zielona Góra
Brocken
Łódź
London
Eindhoven
Antwerp
Essen
Dortmund
Düsseldorf
Kassel
Leipzig
Ghent
Brussels
Cologne
GERMANY
Dresden
Wrocław
Brighton
Bonn
Chemnitz
Liberec
Sněžka
Opole
Częstochowa
Lille
BELGIUM
Charleroi
Katowice
Frankfurt
Prague
Kraków
Amiens
Ostrava
LUXEMBOURG
Plzeň
CZECHIA
Le Havre
Rouen
Luxembourg
Mannheim
Nuremberg
Caen
Reims
Saarbrücken
Brno
Metz
Paris
Karlsruhe
Stuttgart
SLOVAKIA
Nancy
Strasbourg
Augsburg
Linz
Vienna
Munich
Bratislava
Le Mans
Orléans
Parc national de forêts
Salzburg
AUSTRIA
Győr
Angers
Tours
Basel
Zürich
Zugspitze
Innsbruck
Budapest
Dijon
Besançon
LIECHTENSTEIN
Maps

Let's create a White Sphere

Map3D.swift

```
var material = UnlitMaterial()
globe = ModelEntity(mesh: .generateSphere(radius: radius),
                    materials: [material]
          )
```

- Ignore the warning, we'll mutate `material` later.

Put that image in your Asset Catalog

- `M_earth_baseColor.jpg` is approx. 18MB

Use the Texture of the 🌍!

```
guard let resource = try? await
    TextureResource(named: "M_earth_baseColor") else {
        fatalError("Unable to load texture.")
}
var material = UnlitMaterial(texture: resource)
```

Let's Add Markers/Annotation

- I can see New Delhi & Sidney
- We'll do this with RealityKit Attachments
- They are SwiftUI placed on an Entity

Create Extension.swift

```
extension CLLocationCoordinate2D {
    static let zero     = CLLocationCoordinate2DMake(0, 0)
    static let lima     = CLL...(-12.046373,   -77.042755)
    static let sidney   = CLL...(-19.259970,   146.792007)
    static let newDelhi = CLL...(28.613939,     77.209023)
    static let gaza     = CLL...(31.354675,     34.308826)
    static let quito    = CLL...(-0.180653,    -78.467834)
    static let all = [sidney, newDelhi, lima, zero, quito, gaza]
}
```

- 🇵🇪 🇵🇸 ❤️ and you'll see why it's useful to have Lima & Gaza

First display on the 2D Map

```
Map {
    Marker("🇵🇸 Gaza", coordinate: .gaza)
    Marker("🇮🇳 New Delhi", coordinate: .newDelhi)
}
```

Add a second one to “dezoom” the map

Models.swift mimics Markers

```
import MapKit
import SwiftUI

struct Marker3D {
    var text: String
    var coordinate: CLLocationCoordinate2D

    init(_ text: String, coordinate: CLLocationCoordinate2D) {
        self.text = text
        self.coordinate = coordinate
    }
    var marker: Marker<Text> { .init(text, coordinate: coordinate) }
}   // We'll use this in 2D...
```

Add an AppModel in that file

```
@Observable class AppModel {
    static let radius: Float = 0.4
    var markers = [
        Marker3D("🇪🇨 Quito",     coordinate: .quito),
        Marker3D("🇵🇸 Gaza",      coordinate: .gaza),
        Marker3D("🇵🇪 Lima",      coordinate: .lima),
        Marker3D("🦘 Sidney",     coordinate: .sidney),
        Marker3D("🇮🇳 New Delhi", coordinate: .newDelhi),
        Marker3D("🌎 Zero",       coordinate: .zero)
    ]
}
```

Pass the Model

```
struct MapKit3D: App {
    let model = AppModel()

    var body: some Scene {
        WindowGroup(id: "a") {
          ContentView()
            .environment(model)
        }
        WindowGroup(id: "g") {
          Map3D()
            .environment(model)
        ...
```

```
#Preview(windowStyle: .automatic) {
    ContentView()
        .glassBackgroundEffect()
        .environment(AppModel())
}
```

Use the App Model

```
struct ContentView: View {
    @Environment(\.openWindow) private var openWindow
    @Environment(AppModel.self) private var model

    var body: some View {
      Map {
          ForEach(model.markers) { $0.marker.tint(.yellow) }
      }                           //          --------------
    }                             // I can't see those Red Pins!
}
```

Requires that 'Marker3D' conform to 'Identifiable'

```
extension Marker3D: Identifiable {
    var id: String { "\(Int(coordinate.latitude
        )), \(Int(coordinate.longitude))"
    }
}
```

Move the Content of the Map

```
Map { Content2D() }

struct Content2D: MapContent {
    @Environment(AppModel.self) private var model

    var body: some MapContent {
        ForEach(model.markers) {
            $0.marker
                .tint(.yellow)
        }
    }
}                                   // I've tried/failed a Content3D...
```

Create the Attachments

```
@Environment(AppModel.self) private var model

RealityView { content, attachments in
   ...
} attachments: {
  ForEach(model.markers) { marker in
    Attachment(id: marker.coordinate) {
        Text(marker.text).padding().glassBackgroundEffect()
} } }
```

'CLLocationCoordinate2D' does not conform to expected type 'Hashable'

```
extension CLLocationCoordinate2D: @retroactive Hashable {
    public static func == (lhs: Self, rhs: Self) -> Bool {
        lhs.latitude == rhs.latitude && lhs.longitude == rhs.longitude
    }

    public func hash(into hasher: inout Hasher) {
        hasher.combine(latitude)
        hasher.combine(longitude)
    }
}
```

Add the Attachments

```
RealityView { content, attachments in
  add(attachments)
} attachments: { ... }

private func add(_ attachments: RealityViewAttachments) {
  for marker in model.markers {
    if let attachment = attachments.entity(for: marker.coordinate) {
      globe.addChild(attachment)
    }
  }
}
```

Wait, where is it?

- Can anyone guess where it is?
- Hint: We didn’t position the entity anywhere
- So…
- Zoom inside your globe…

Yes, it's inside!

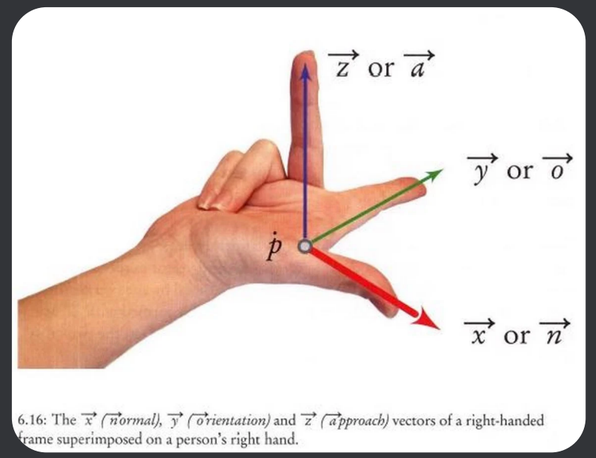
- All of them, stacked on top of each other
- At position 0, 0, 0 in the 3D Space!

Position the Attachments

```
if let attachment = attachments.entity(for: marker) {
    attachment.position = /* what? *
    entity.addChild(attachment)
}
```

- We need to map Lat/Lon to the 3D Space!
- StackOverflow to the rescue! (**Screw you**, ChatGPT!)

```
// In the Cartesian coordinate system, the conversion is:
x = RADIUS * cos(lat) * cos(lon) // longitude (meeting the equator)
y = RADIUS * cos(lat) * sin(lon) // latitude  (meeting Greenwich)
z = RADIUS * sin(lat)            // goes through the poles.
```



[1]

If your trigonometric functions expect radians (which they do),

you will need to convert your longitude and latitude to radians first.

[1] CC: flickr/photos/rutty/492385781, re-thinkingthefuture.com

Add to your Marker3D

```
func coords(for radius: Float) -> SIMD3<Float> {
  [0, 0, 0]
}
```

- We'll return X, Y, Z
- We'll write the code in a minute...

Time for a Unit Test

- New Target, Test
- New File, Swift Testing Unit Test
- `Test.swift`, No Briding Header!
- Only add in the Test Target
- Add `Models.swift` in that Target

```swift
import Testing

struct Tests {
    private let coord = Marker3D("Quito", coordinate: .quito)
                        .coords(for: 0.4)

    @Test func coords() async throws {
        #expect(coord.x == 0.07996686)
        #expect(coord.y == -0.39192313)
        #expect(coord.z == -0.0012611939)
    }
}
```

- Start the Unit Test, should be red

Fix coords and the Unit Test

```
let lat = Float(coordinate.latitude) * .pi / 180
let lon = Float(coordinate.longitude) * .pi / 180
let coords: SIMD3<Float> = [
    radius * cos(lat) * cos(lon),
    radius * cos(lat) * sin(lon),
    radius * sin(lat)
]
return coords
```

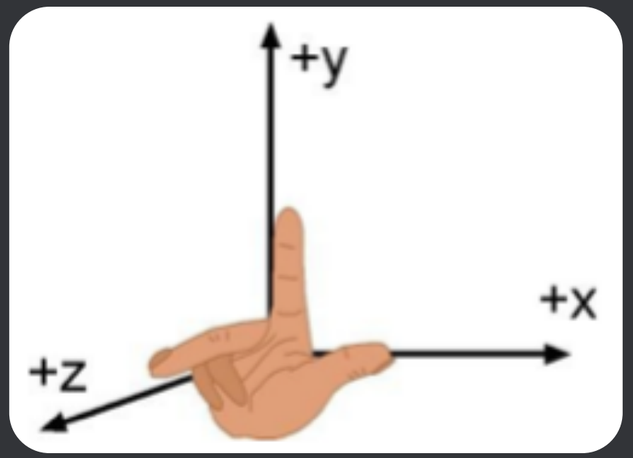
Houston, we have TWO Problems

1. Gaza in the Pacific, New Delhi in Russia, ...
2. Attachments face to us
   - They should face the Globe!
   - Replace `.position =` with `.look(at: from:)`
   - Can you guess the `at`?
     - `[0,0,0]`, the center of the earth!

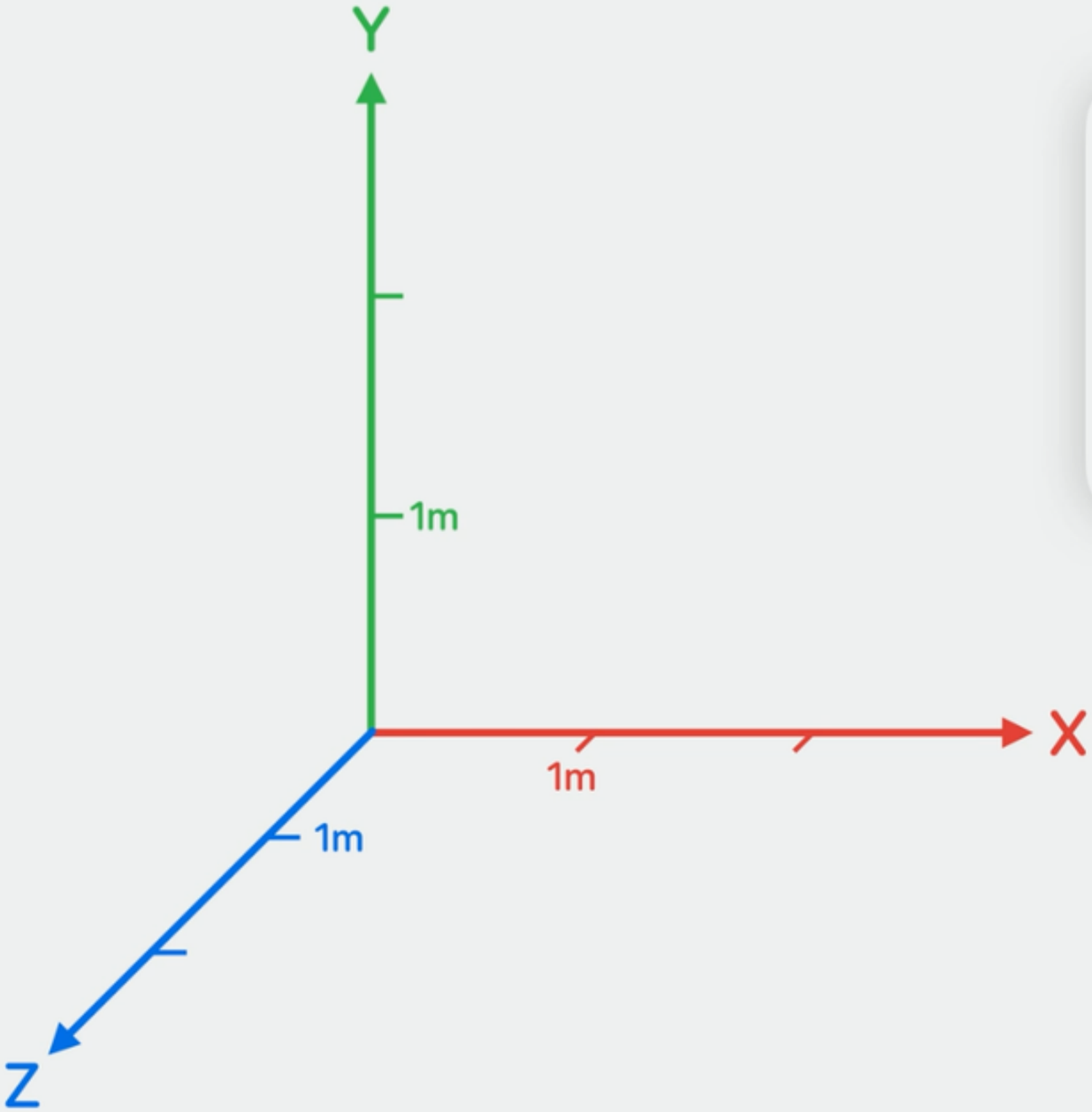
```
attachment.look(
    at: [0,0,0],
    from: coords,
    relativeTo: globe
)
```

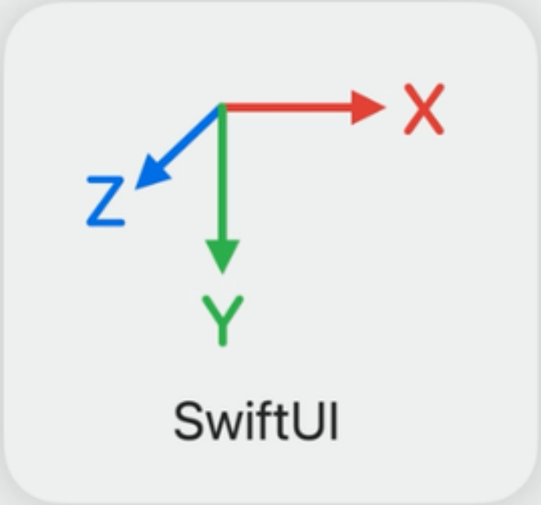
`relativeTo` optional, but …

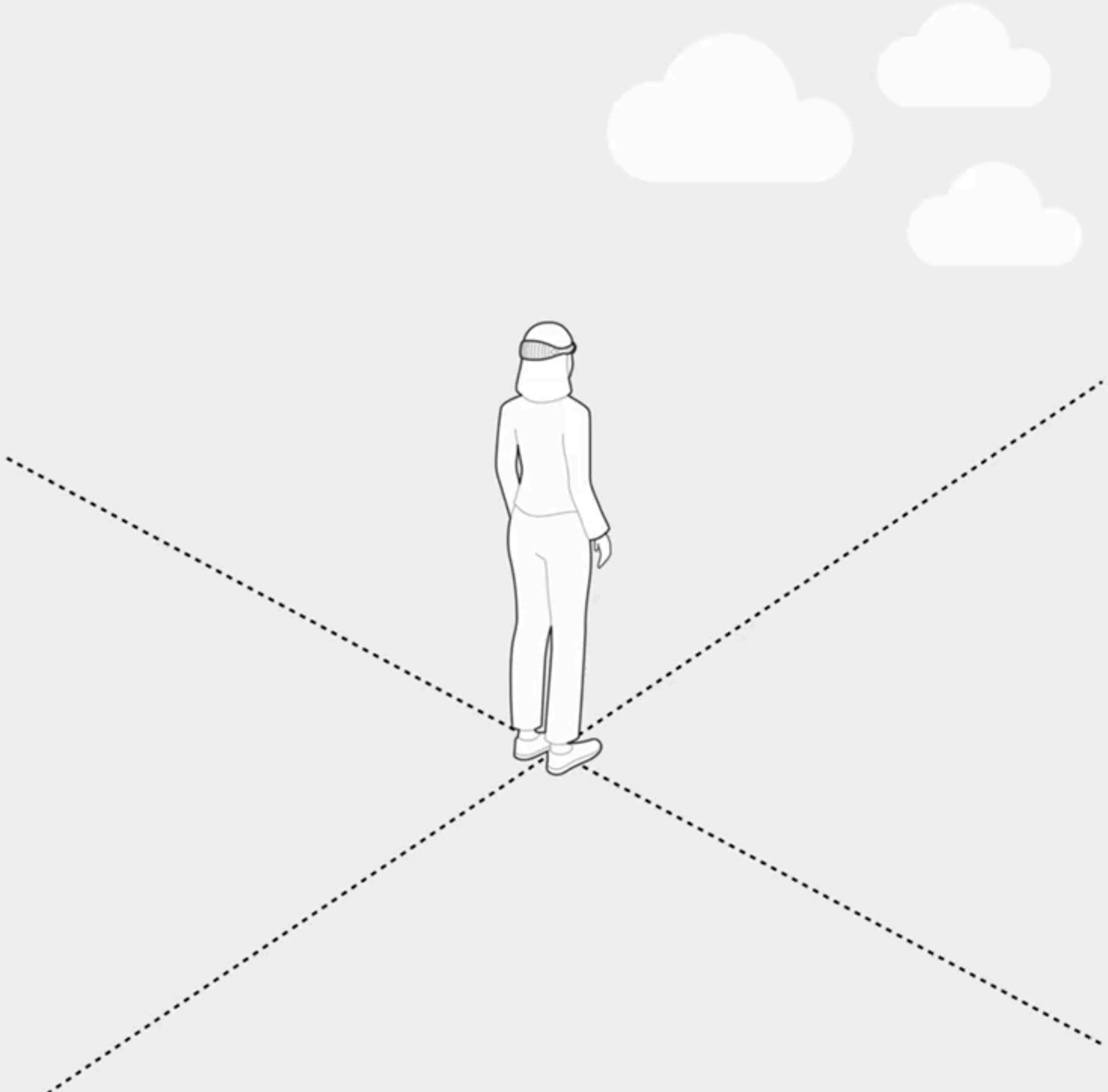
In RealityKit:



Coordinate spaces







Rotate 90° on your X axis!

```
from: coords * simd_quatf(angle: .pi/2, axis: [1, 0, 0])
```

The compiler is unable to type-check this expression in reasonable time; try breaking up the expression into distinct sub-expressions

OR

Cannot convert value of type 'simd*quatf' to expected argument type 'simd*float3x3'

Let's break up & fix in Extension.swift

```
from: coords * (pi / 2).rotateX // We'll need it later

extension Float {
    var rotateX: simd_float3x3 {
        simd_matrix3x3(simd_quatf(angle: self, axis: [1, 0, 0]))
    }
}

@Test func coordsRotated() ... // Create this now
```

Lima is up again!

- I can tell the latitudes are good!
- What's wrong with our Longitude?
- Our texture doesn't start at Greenwich
  - But left from Alaska, at -90º!

We need to slide the texture!

```
var material = UnlitMaterial(texture: resource)

material.textureCoordinateTransform =
    .init(offset: SIMD2<Float>(x:0.5, y: 0))
```

- Now we see America instead of Asia
- And our Markers are correct! 🎉
- I told you I'll make this **var** useful!

Easier, take this texture

```
let material = UnlitMaterial(texture: resource)
```

- Replace with `M_earth_baseColor_greenwich.jpg`
- Otherwise it will make the code more complicated
- Remove the `.textureCoordinate` and make `let material` 🎉

Let's travel a bit more

```
static let la      = (34.052235 , -118.243683)
static let phoenix = (33.44825,   -112.07662 )
static let dallas  = (32.77557  ,  -96.79560 )
static let madrid  = (40.416775 ,   -3.703790)
```

Adding new attachments

```
NavigationStack {
    Map { ... }
      .toolbar {
          Button("Add") {
              model.markers.append(Marker3D("🇺🇸 LA",     coordinate: .la)    )
              model.markers.append(Marker3D("🇪🇸 Madrid", coordinate: .madrid))
          }
      }
      .font(.extraLargeTitle)
}
.onAppear {
    openWindow(id: "g")
}   // This is to simulate a more sophisticated UI for adding/searching...
```

Added to 2D and 3D, but...

- Why nothing happens?
- We are `@Observable`, `@State`, @Environment
  - Everything good, no?
- RealityKit won't refresh all the `RealityView`
  - Only `attachments:` and ...

Add the `update:` block

```
RealityView { content, attachments in
   ...
} update: { content, attachments in
    if let globe {
        add(attachments)
    }
} attachments: {
    ...
}
```


Lima
2
Add
North Atlantic Ocean
Caracas
Bogotá
SOUTH AMERICA
Lima
Brasília
Maps
Cairo
Gaza
AFRICA
Lagos
Kinshasa
Luanda

A bug? PBKAC...

```
content.remove(globe)
add(attachments)
content.add(globe)
```

- Only in the `update` block
- I'm not happy about it...

Now let's add a Marker when we tap the globe!

```
realityView
    .gesture(spatialGesture)

private var spatialGesture: some Gesture {
    SpatialTapGesture().targetedToAnyEntity().onEnded {
        var pos = $0.convert($0.location3D, from: .local, to: .scene)
        pos = globe.convert(position: pos, from: nil)
        // We need revert our orientation
        pos = pos * (-.pi / 2).rotateX
        print(pos)
    }
}
```

Nothing prints because no Components!

```
globe.components.set(
    [
        CollisionComponent(shapes:
            [.generateSphere(radius: AppModel.radius)]
        ),
        InputTargetComponent()
    ]
)
```

```swift
private let converted = SIMD3<Float>(
    -0.027481655,
    -0.31684208,
    -0.23480688
)
var pos: SIMD3<Float> { converted * (-.pi/2).rotateX }

@Test func convert() async throws {
    #expect(pos.x == -0.027481655)
    #expect(pos.y ==  0.23480685)
    #expect(pos.z == -0.3168421)
}
```

Get lat/lon from X,Y,Z

```
extension SIMD3<Float> {
    func latitude(for radius: Float) -> Double {
        Double(asin(z / radius) * 180 / .pi)
    }
    var longitude: Double { Double(atan2(y, x) * 180 / .pi) }
}

@Test func latlon() async throws // write this ...
```

Reverse Geolocation!

```
Task { await reverse(latitude: pos.latitude(for: AppModel.radius),
                     longitude: pos.longitude)
}
private let coder = CLGeocoder()
private func reverse(latitude: Double, longitude: Double) async {
  let location = CLLocation(latitude: latitude, longitude: longitude)
  if let placemark = try! await coder.reverseGeocodeLocation(location).first {
    model.markers.append(
      Marker3D(placemark.locality ?? "?", coordinate: location.coordinate)
) } }

@Test func placemark() // write this...
```

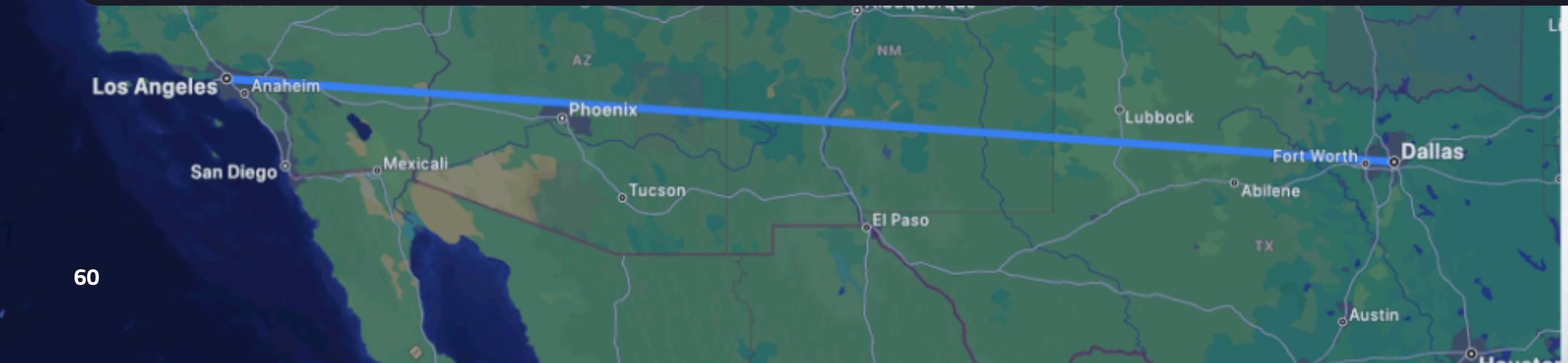
Let's go from Dallas to LA!

```
struct MapPolyline3D {
    private(set) var coordinates: [CLLocationCoordinate2D]

    var polyline: MapPolyline {
        .init(coordinates: coordinates)
    }
}
class AppModel {
    var polylines = [MapPolyline3D]()

    init() {
        polyline = [MapPolyline3D(coordinates: [.la, .dallas])]
    }
```

```
Map(initialPosition: .region(.init(center: .phoenix,
    span: .init(latitudeDelta: 15, longitudeDelta: 15)))) {
    Content2D()
}
var body: some MapContent {
    ...
    ForEach(model.polylines) {
        $0.polyline.stroke(.blue, lineWidth: 5)
    }
}
```



Calculate the points between the route

```
struct MapPolyline3D {
    mutating func calculate() async {
        guard let source = coordinates.first,
              let destination = coordinates.last else { return }
        let request = MKDirections.Request()
        ...
    }
}
```

```
request.source = MKMapItem(placemark: MKPlacemark(coordinate: source,
                   addressDictionary: nil))
request.destination = MKMapItem(placemark: MKPlacemark(coordinate: destination,
                                                addressDictionary: nil))
request.transportType = .automobile
do {
    if let route = try await MKDirections(request: request)
        .calculate().routes.first {
            let count = route.polyline.coordinates.count
            if count > 2 {
                coordinates = []
                let indices = stride(from: 0,
                                     through: count - 1,
                                     by: (count - 1) / 251) // Approx UInt8
                indices.forEach { coordinates.append(route.polyline.coordinates[$0]) }
} } } } catch {
    print(error)
}
```

Value of type 'MKPolyline' has no member 'coordinates'

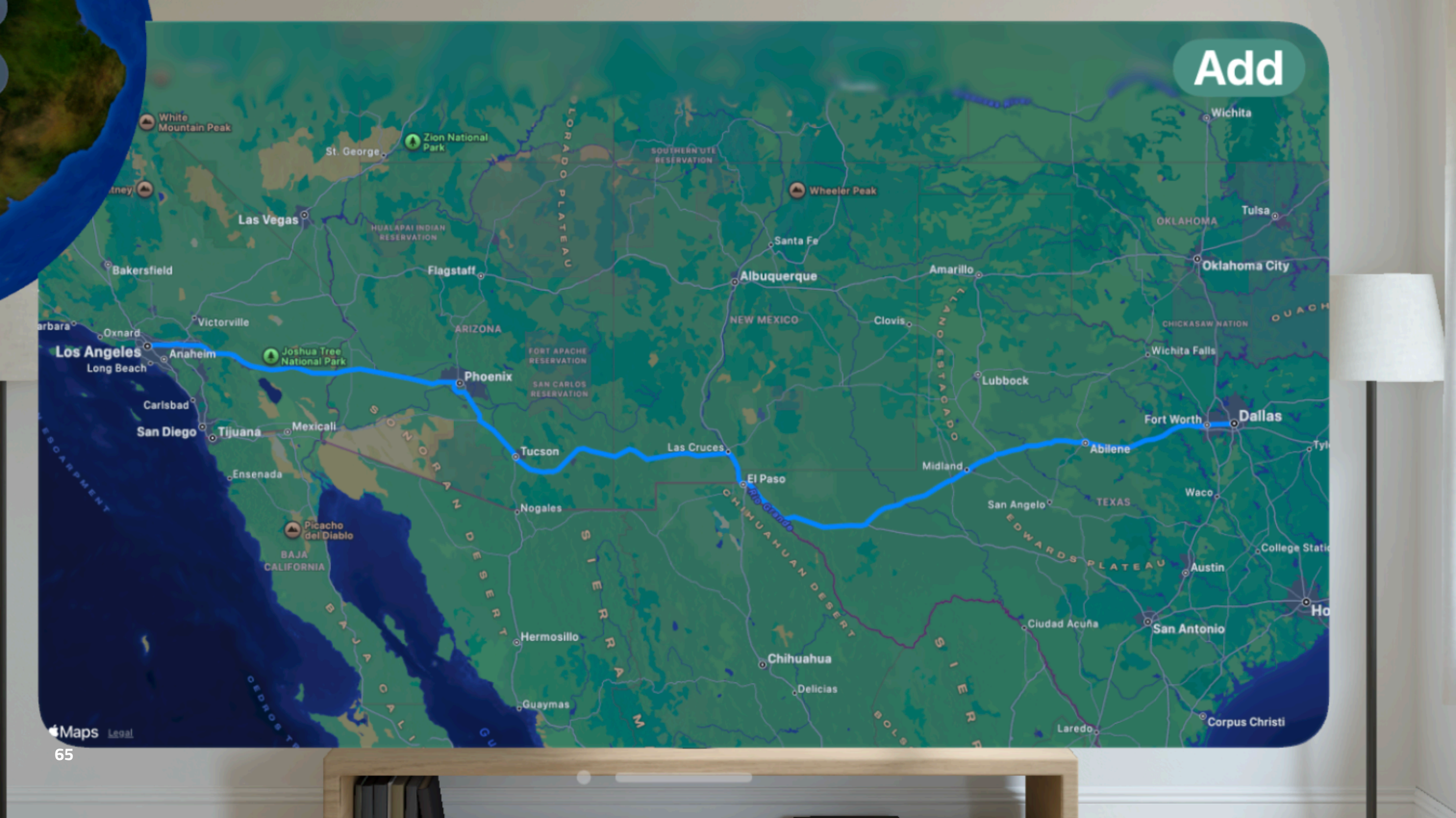
```
public extension MKMultiPoint {
    var coordinates: [CLLocationCoordinate2D] {
        var coords = [CLLocationCoordinate2D](repeating: kCLLocationCoordinate2DInvalid,
                                              count: pointCount)

        getCoordinates(&coords, range: NSRange(location: 0, length: pointCount))
        return coords
    }
}
```

Augment to calculate...

```
class AppModel {
    var polylines = [MapPolyline3D]()

    init() {
        var polyline = MapPolyline3D(coordinates: [.la, .dallas])
        Task {
            await polyline.calculate()
            self.polylines = [polyline]
        }
    }
```


Add
White Mountain Peak
Zion National Park
St. George
Las Vegas
HUALAPAI INDIAN RESERVATION
Bakersfield
Flagstaff
Victorville
Oxnard
Los Angeles
Anaheim
Long Beach
Joshua Tree National Park
Carlsbad
San Diego
Tijuana
Mexicali
Ensenada
Picacho del Diablo
BAJA CALIFORNIA
ARIZONA
Phoenix
FORT APACHE RESERVATION
SAN CARLOS RESERVATION
Tucson
Nogales
Hermosillo
Guaymas
SONORAN DESERT
SIERRA MADRE
COLORADO PLATEAU
SOUTHERN UTE RESERVATION
Wheeler Peak
Santa Fe
Albuquerque
NEW MEXICO
Las Cruces
El Paso
Rio Grande
CHIHUAHUAN DESERT
Chihuahua
Delicias
Amarillo
Clovis
LLANO ESTACADO
Lubbock
Midland
San Angelo
EDWARDS PLATEAU
Ciudad Acuña
Laredo
Abilene
Fort Worth
Dallas
Wichita
Tulsa
OKLAHOMA
Oklahoma City
CHICKASAW NATION
Wichita Falls
TEXAS
Waco
Austin
San Antonio
Corpus Christi
Maps
Legal

One way of plotting this route in 3D ...

```
} attachments: {
  ...
  ForEach(model.polylines.coordinates) {
    Attachment(id: $0) {
      Circle().frame(width: 10,
                     height: 10)
      .foregroundStyle(Color.yellow)
    }
  }
}
```

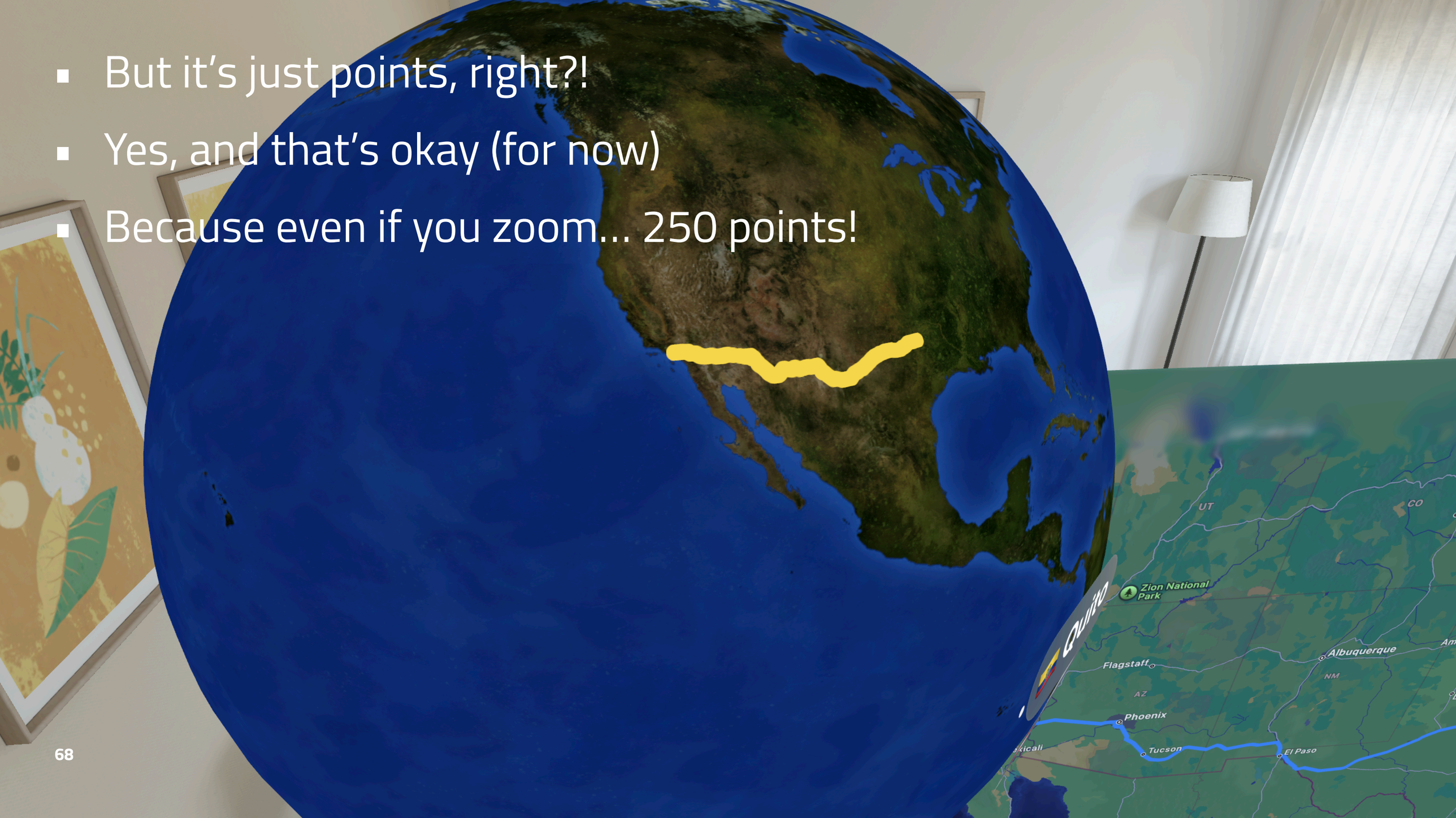
```
extension [MapPolyline3D] {
  var coordinates: [CLLocationCoordinate2D] {
    flatMap(\.coordinates)
  }
}

extension CLLocationCoordinate2D:
  @retroactive Identifiable {

  public var id: String {
    "\(Int(latitude)), \(Int(longitude))"
  }
}
```

```
private func add(_ attachments: RealityViewAttachments,
                 for coordinate: CLLocationCoordinate2D) {
    if let attachment = attachments.entity(for: coordinate) {
        attachment.add(coordinate, to: globe)
    }
}
private func add(_ attachments: RealityViewAttachments) {
    model.markers.forEach {
        add(attachments, for: $0.coordinate)
    }
    model.polylines.coordinates.forEach {
        add(attachments, for: $0)
    }
}
```

- But it’s just points, right?!
- Yes, and that’s okay (for now)
- Because even if you zoom… 250 points!



Polygons, boundingBoxes, States

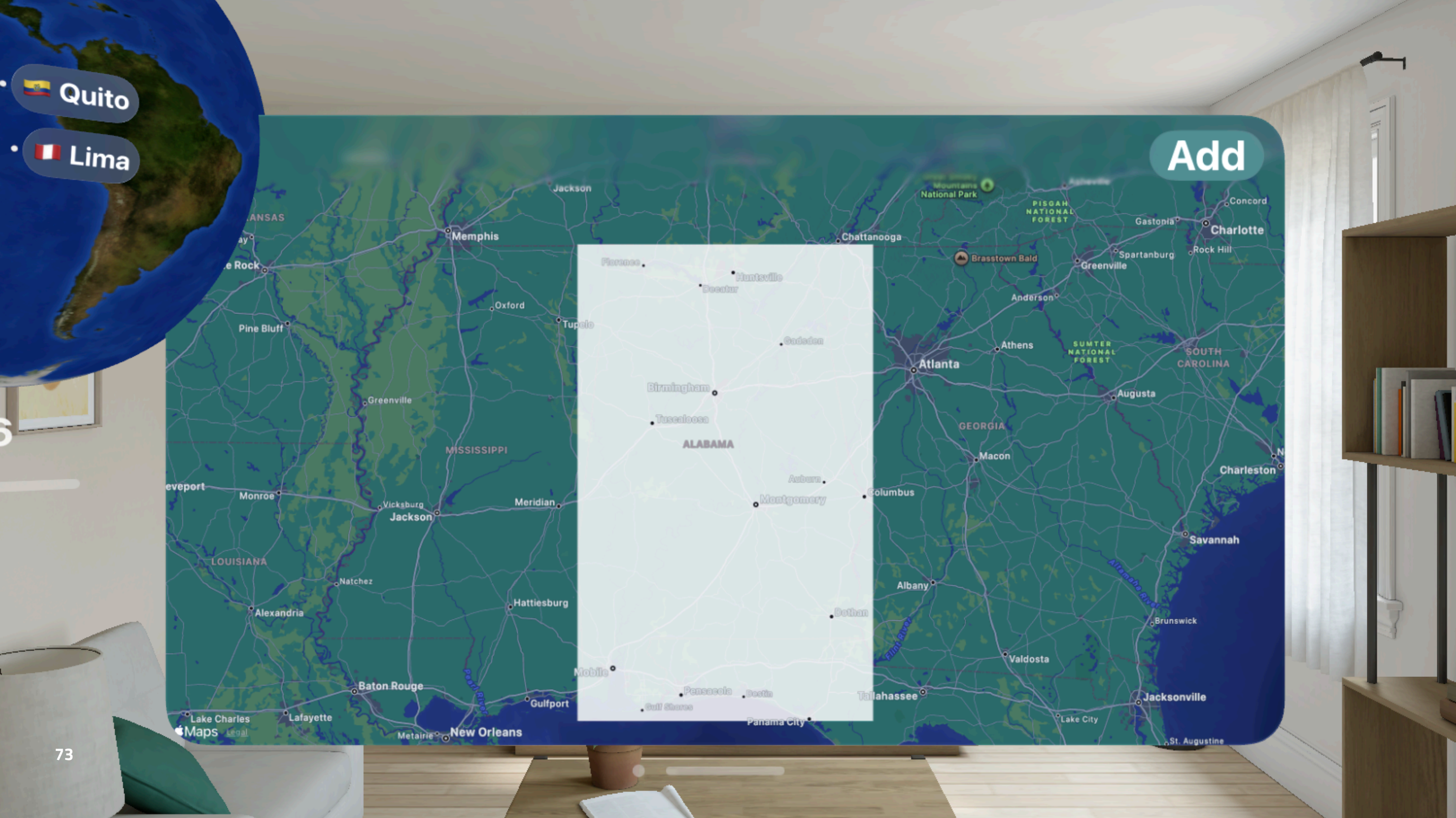
- Sweet home Alabama

```
extension [CLLocationCoordinate2D] {
    static let alabama = [
        CLLocationCoordinate2DMake(30.1375217437744,
                                   -84.8882446289062),  // South West (Bristol, FL)
        CLLocationCoordinate2DMake(35.0080299377441,
                                   -88.4731369018555),  // North East (Michie, TN)
    ]
}
```

```
var box: [CLLocationCoordinate2D] {
    if count != 2 {
        assertionFailure("Only allowed with 2 coordinates, not \(count)")
        return []
    }
    guard let first, let last else {
        assertionFailure("Could not get min/max (first/last)")
        return []
    }
    return [
        CLLocationCoordinate2DMake(first.latitude, first.longitude),
        CLLocationCoordinate2DMake(first.latitude, last.longitude),
        CLLocationCoordinate2DMake(last.latitude, last.longitude),
        CLLocationCoordinate2DMake(last.latitude, first.longitude)
    ]
}
```

Poly❤️ first in 2D

```
class AppModel {
    ...
    var polygons = [MapPolygon3D(coordinates: .alabama.box)]
}
var body: some MapContent {
  ...
  ForEach(model.polygons) {
      $0.mapPolygon
          .tint(.gray) // .opacity?
  }
  ...
```


Quito
Lima
Add
Jackson
Memphis
Chattanooga
Brasstown Bald
Greenville
Spartanburg
Gastonia
Charlotte
Concord
Rock Hill
Anderson
Athens
Atlanta
Augusta
Macon
Columbus
Charleston
Savannah
Brunswick
Jacksonville
St. Augustine
Lake City
Valdosta
Albany
Tallahassee
Panama City
Dothan
Montgomery
Auburn
Birmingham
Tuscaloosa
Gadsden
Huntsville
Decatur
Florence
Mobile
Pensacola
Destin
Gulf Shores
Oxford
Tupelo
Pine Bluff
Greenville
Vicksburg
Jackson
Meridian
Monroe
Natchez
Alexandria
Hattiesburg
Baton Rouge
Gulfport
Lake Charles
Lafayette
Metairie
New Orleans
ALABAMA
MISSISSIPPI
LOUISIANA
GEORGIA
SOUTH CAROLINA
PISGAH NATIONAL FOREST
SUMTER NATIONAL FOREST
National Park
Maps

Now let's create a Polygon in 3D

```
extension ModelEntity {
    static func with(coordinates: [CLLocationCoordinate2D]) async
        -> ModelEntity {

        let points = coordinates.map {
            $0.simd3(for: AppModel.radius * 1.02)
        }
        ...
    }
}
```

```
...
var descriptor = MeshDescriptor()
descriptor.positions = MeshBuffers.Positions(points)
descriptor.primitives = .polygons(
    [UInt8(points.count)],
    points.indices.map { UInt32($0) }
)
let resource = try! await MeshResource(from: [descriptor])
return ModelEntity(mesh: resource)
```

```
RealityView { content, attachments in
    ...
    await globe.addChild(
        ModelEntity.with(coordinates: .alabama.box)
    )
```

- But now… crickets…
- Except if you zoom, pan, …


Zero
Gaza
New
UNITED STATES
Denver
Colorado Springs
Wichita
Tulsa
Oklahoma City
Kansas City
Little Rock
CO
KS
OK
AR

Quito

Reverse the dots!

```
points.indices.reversed().map { UInt32($0) }
```

- Thanks Matthias Weber!
- … aaand, that’s it!

Pizzatime!

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Thanks!