Chris Anderson: Elon Musk,

great to see you.

How are you?

Elon Musk: Good. How are you?

CA: We're here at the Texas Gigafactory

the day before this thing opens.

It's been pretty crazy out there.

Thank you so much

for making time on a busy day.

I would love you to help us,

kind of, cast our minds,

I don't know, 10, 20,

30 years into the future.

And help us try to picture

what it would take

to build a future that's worth

getting excited about.

The last time you spoke at TED,

you said that that was really

just a big driver.

You know, you can talk about lots of other

reasons to do the work you're doing,

but fundamentally, you want

to think about the future

and not think that it sucks.

EM: Yeah, absolutely.

I think in general, you know,

there's a lot of discussion of like,

this problem or that problem.

And a lot of people are sad

about the future

and they're ...

Pessimistic.

And I think ...

this is ...

This is not great.

I mean, we really want

to wake up in the morning

and look forward to the future.

We want to be excited

about what's going to happen.

And life cannot simply be about sort of,

solving one miserable

problem after another.

CA: So if you look forward 30 years,

you know, the year 2050

has been labeled by scientists

as this, kind of, almost like this

doomsday deadline on climate.

There's a consensus of scientists,

a large consensus of scientists,

who believe that if we haven't

completely eliminated greenhouse gases

or offset them completely by 2050,

effectively we're inviting

climate catastrophe.

Do you believe there is a pathway

to avoid that catastrophe?

And what would it look like?

EM: Yeah, so I am not one

of the doomsday people,

which may surprise you.

I actually think we're on a good path.

But at the same time,

I want to caution against complacency.

So, so long as we are not complacent,

as long as we have a high sense of urgency

about moving towards

a sustainable energy economy,

then I think things will be fine.

So I can't emphasize that enough,

as long as we push hard

and are not complacent,

the future is going to be great.

Don't worry about it.

I mean, worry about it,

but if you worry about it, ironically,

it will be a self-unfulfilling prophecy.

So, like, there are three elements

to a sustainable energy future.

One is of sustainable energy generation,

which is primarily wind and solar.

There's also hydro, geothermal,

I'm actually pro-nuclear.

I think nuclear is fine.

But it's going to be primarily

solar and wind,

as the primary generators of energy.

The second part is you need batteries

to store the solar and wind energy

because the sun

doesn't shine all the time,

the wind doesn't blow all the time.

So it's a lot of stationary battery packs.

And then you need electric transport.

So electric cars, electric planes, boats.

And then ultimately,

it’s not really possible

to make electric rockets,

but you can make

the propellant used in rockets

using sustainable energy.

So ultimately, we can have a fully

sustainable energy economy.

And it's those three things:

solar/wind, stationary

battery pack, electric vehicles.

So then what are the limiting

factors on progress?

The limiting factor really will be

battery cell production.

So that's going to really be

the fundamental rate driver.

And then whatever the slowest element

of the whole lithium-ion

battery cells supply chain,

from mining and the many steps of refining

to ultimately creating a battery cell

and putting it into a pack,

that will be the limiting factor

on progress towards sustainability.

CA: All right, so we need to talk

more about batteries,

because the key thing

that I want to understand,

like, there seems to be

a scaling issue here

that is kind of amazing and alarming.

You have said that you have calculated

that the amount of battery production

that the world needs for sustainability

is 300 terawatt hours of batteries.

That's the end goal?

EM: Very rough numbers,

and I certainly would invite others

to check our calculations

because they may arrive

at different conclusions.

But in order to transition, not just

current electricity production,

but also heating and transport,

which roughly triples the amount

of electricity that you need,

it amounts to approximately 300 terawatt

hours of installed capacity.

CA: So we need to give people

a sense of how big a task that is.

I mean, here we are at the Gigafactory.

You know, this is one of the biggest

buildings in the world.

What I've read, and tell me

if this is still right,

is that the goal here is to eventually

produce 100 gigawatt hours

of batteries here a year eventually.

EM: We will probably do more than that,

but yes, hopefully we get there

within a couple of years.

CA: Right.

But I mean, that is one --

EM: 0.1 terrawat hours.

CA: But that's still 1/100

of what's needed.

How much of the rest of that 100

is Tesla planning to take on

let's say, between now and 2030, 2040,

when we really need to see

the scale up happen?

EM: I mean, these are just guesses.

So please, people shouldn't

hold me to these things.

It's not like this is like some --

What tends to happen

is I'll make some like,

you know, best guess

and then people, in five years,

there’ll be some jerk

that writes an article:

"Elon said this would happen,

and it didn't happen.

He's a liar and a fool."

It's very annoying when that happens.

So these are just guesses,

this is a conversation.

CA: Right.

EM: I think Tesla probably ends up

doing 10 percent of that.

Roughly.

CA: Let's say 2050

we have this amazing, you know,

100 percent sustainable electric grid

made up of, you know, some mixture

of the sustainable energy sources

you talked about.

That same grid probably

is offering the world

really low-cost energy, isn't it,

compared with now.

And I'm curious about like,

are people entitled to get

a little bit excited

about the possibilities of that world?

EM: People should be optimistic

about the future.

Humanity will solve sustainable energy.

It will happen if we, you know,

continue to push hard,

the future is bright and good

from an energy standpoint.

And then it will be possible to also use

that energy to do carbon sequestration.

It takes a lot of energy to pull

carbon out of the atmosphere

because in putting it in the atmosphere

it releases energy.

So now, you know, obviously

in order to pull it out,

you need to use a lot of energy.

But if you've got a lot of sustainable

energy from wind and solar,

you can actually sequester carbon.

So you can reverse the CO2 parts

per million of the atmosphere and oceans.

And also you can really have

as much fresh water as you want.

Earth is mostly water.

We should call Earth “Water.”

It's 70 percent water by surface area.

Now most of that’s seawater,

but it's like we just happen to be

on the bit that's land.

CA: And with energy,

you can turn seawater into --

EM: Yes.

CA: Irrigating water

or whatever water you need.

EM: At very low cost.

Things will be good.

CA: Things will be good.

And also, there's other benefits

to this non-fossil fuel world

where the air is cleaner --

EM: Yes, exactly.

Because, like, when you burn fossil fuels,

there's all these side reactions

and toxic gases of various kinds.

And sort of little particulates

that are bad for your lungs.

Like, there's all sorts

of bad things that are happening

that will go away.

And the sky will be cleaner and quieter.

The future's going to be good.

CA: I want us to switch now to think

a bit about artificial intelligence.

But the segue there,

you mentioned how annoying it is

when people call you up

for bad predictions in the past.

So I'm possibly going to be annoying now,

but I’m curious about your timelines

and how you predict

and how come some things are so amazingly

on the money and some aren't.

So when it comes to predicting sales

of Tesla vehicles, for example,

you've kind of been amazing,

I think in 2014 when Tesla

had sold that year 60,000 cars,

you said, "2020, I think we will do

half a million a year."

EM: Yeah, we did

almost exactly a half million.

CA: You did almost exactly half a million.

You were scoffed in 2014

because no one since Henry Ford,

with the Model T, had come close

to that kind of growth rate for cars.

You were scoffed, and you actually

hit 500,000 cars

and then 510,000 or whatever produced.

But five years ago,

last time you came to TED,

I asked you about full self-driving,

and you said, “Yeah, this very year,

I'm confident that we will have a car

going from LA to New York

without any intervention."

EM: Yeah, I don't want to blow your mind,

but I'm not always right.

CA: (Laughs)

What's the difference between those two?

Why has full self-driving in particular

been so hard to predict?

EM: I mean, the thing that really got me,

and I think it's going to get

a lot of other people,

is that there are just so many

false dawns with self-driving,

where you think you've got the problem,

have a handle on the problem,

and then it, no, turns out

you just hit a ceiling.

Because if you were to plot the progress,

the progress looks like a log curve.

So it's like a series of log curves.

So most people don't know

what a log curve is, I suppose.

CA: Show the shape with your hands.

EM: It goes up you know,

sort of a fairly straight way,

and then it starts tailing off

and you start getting diminishing returns.

And you're like, uh oh,

it was trending up and now

it's sort of, curving over

and you start getting to these,

what I call local maxima,

where you don't realize

basically how dumb you were.

And then it happens again.

And ultimately...

These things, you know,

in retrospect, they seem obvious,

but in order to solve

full self-driving properly,

you actually have to solve real-world AI.

Because what are the road networks

designed to work with?

They're designed to work

with a biological neural net, our brains,

and with vision, our eyes.

And so in order to make it

work with computers,

you basically need to solve

real-world AI and vision.

Because we need cameras

and silicon neural nets

in order to have self-driving work

for a system that was designed

for eyes and biological neural nets.

You know, I guess

when you put it that way,

it's sort of, like, quite obvious

that the only way

to solve full self-driving

is to solve real world AI

and sophisticated vision.

CA: What do you feel

about the current architecture?

Do you think you have an architecture now

where there is a chance

for the logarithmic curve

not to tail off any anytime soon?

EM: Well I mean, admittedly

these may be infamous last words,

but I actually am confident

that we will solve it this year.

That we will exceed --

The probability of an accident,

at what point do you exceed

that of the average person?

I think we will exceed that this year.

CA: What are you seeing behind the scenes

that gives you that confidence?

EM: We’re almost at the point

where we have a high-quality

unified vector space.

In the beginning, we were trying

to do this with image recognition

on individual images.

But if you get one image out of a video,

it's actually quite hard to see

what's going on without ambiguity.

But if you look at a video segment

of a few seconds of video,

that ambiguity resolves.

So the first thing we had to do

is tie all eight cameras together

so they're synchronized,

so that all the frames

are looked at simultaneously

and labeled simultaneously by one person,

because we still need human labeling.

So at least they’re not labeled

at different times by different people

in different ways.

So it's sort of a surround picture.

Then a very important part

is to add the time dimension.

So that you’re looking at surround video,

and you're labeling surround video.

And this is actually quite difficult to do

from a software standpoint.

We had to write our own labeling tools

and then create auto labeling,

create auto labeling software to amplify

the efficiency of human labelers

because it’s quite hard to label.

In the beginning,

it was taking several hours

to label a 10-second video clip.

This is not scalable.

So basically what you have to have

is you have to have surround video,

and that surround video has to be

primarily automatically labeled

with humans just being editors

and making slight corrections

to the labeling of the video

and then feeding back those corrections

into the future auto labeler,

so you get this flywheel eventually

where the auto labeler

is able to take in vast amounts of video

and with high accuracy,

automatically label the video

for cars, lane lines, drive space.

CA: What you’re saying is ...

the result of this is that you're

effectively giving the car a 3D model

of the actual objects

that are all around it.

It knows what they are,

and it knows how fast they are moving.

And the remaining task is to predict

what the quirky behaviors are

that, you know,

that when a pedestrian is walking

down the road with a smaller pedestrian,

that maybe that smaller pedestrian

might do something unpredictable

or things like that.

You have to build into it

before you can really call it safe.

EM: You basically need to have

memory across time and space.

So what I mean by that is ...

Memory can’t be infinite,

because it's using up a lot

of the computer's RAM basically.

So you have to say how much

are you going to try to remember?

It's very common

for things to be occluded.

So if you talk about say,

a pedestrian walking past a truck

where you saw the pedestrian start

on one side of the truck,

then they're occluded by the truck.

You would know intuitively,

OK, that pedestrian is going to pop out

the other side, most likely.

CA: A computer doesn't know it.

EM: You need to slow down.

CA: A skeptic is going to say

that every year for the last five years,

you've kind of said, well,

no this is the year,

we're confident that it will be there

in a year or two or, you know,

like it's always been about that far away.

But we've got a new architecture now,

you're seeing enough improvement

behind the scenes

to make you not certain,

but pretty confident,

that, by the end of this year,

what in most, not in every city,

and every circumstance

but in many cities and circumstances,

basically the car will be able

to drive without interventions

safer than a human.

EM: Yes.

I mean, the car currently

drives me around Austin

most of the time with no interventions.

So it's not like ...

And we have over 100,000 people

in our full self-driving beta program.

So you can look at the videos

that they post online.

CA: I do.

And some of them are great,

and some of them are a little terrifying.

I mean, occasionally

the car seems to veer off

and scare the hell out of people.

EM: It’s still a beta.

CA: But you’re behind the scenes,

looking at the data,

you're seeing enough improvement

to believe that a this-year

timeline is real.

EM: Yes, that's what it seems like.

I mean, we could be here

talking again in a year,

like, well, another year went by,

and it didn’t happen.

But I think this is the year.

CA: And so in general,

when people talk about Elon time,

I mean it sounds like

you can't just have a general rule

that if you predict that something

will be done in six months,

actually what we should imagine

is it’s going to be a year

or it’s like two-x or three-x,

it depends on the type of prediction.

Some things, I guess,

things involving software, AI, whatever,

are fundamentally harder

to predict than others.

Is there an element

that you actually deliberately make

aggressive prediction timelines

to drive people to be ambitious?

Without that, nothing gets done?

EM: Well, I generally believe,

in terms of internal timelines,

that we want to set the most aggressive

timeline that we can.

Because there’s sort of like

a law of gaseous expansion where,

for schedules, where

whatever time you set,

it's not going to be less than that.

It's very rare

that it'll be less than that.

But as far as our predictions

are concerned,

what tends to happen in the media

is that they will report

all the wrong ones

and ignore all the right ones.

Or, you know, when writing

an article about me --

I've had a long career

in multiple industries.

If you list my sins, I sound

like the worst person on Earth.

But if you put those

against the things I've done right,

it makes much more sense, you know?

So essentially like,

the longer you do anything,

the more mistakes

that you will make cumulatively.

Which, if you sum up those mistakes,

will sound like I'm the worst

predictor ever.

But for example, for Tesla vehicle growth,

I said I think we’d do 50 percent,

and we’ve done 80 percent.

CA: Yes.

EM: But they don't mention that one.

So, I mean, I'm not sure what my exact

track record is on predictions.

They're more optimistic than pessimistic,

but they're not all optimistic.

Some of them are exceeded

probably more or later,

but they do come true.

It's very rare that they do not come true.

It's sort of like, you know,

if there's some radical

technology prediction,

the point is not

that it was a few years late,

but that it happened at all.

That's the more important part.

CA: So it feels like

at some point in the last year,

seeing the progress on understanding,

the Tesla AI understanding

the world around it,

led to a kind of, an aha moment at Tesla.

Because you really surprised people

recently when you said

probably the most important

product development

going on at Tesla this year

is this robot, Optimus.

EM: Yes.

CA: Many companies out there

have tried to put out these robots,

they've been working on them for years.

And so far no one has really cracked it.

There's no mass adoption

robot in people's homes.

There are some in manufacturing,

but I would say,

no one's kind of, really cracked it.

Is it something that happened

in the development of full self-driving

that gave you the confidence to say,

"You know what, we could do

something special here."

EM: Yeah, exactly.

So, you know, it took me a while

to sort of realize

that in order to solve self-driving,

you really needed to solve real-world AI.

And at the point of which you solve

real-world AI for a car,

which is really a robot on four wheels,

you can then generalize that

to a robot on legs as well.

The two hard parts I think --

like obviously companies

like Boston Dynamics

have shown that it's possible

to make quite compelling,

sometimes alarming robots.

CA: Right.

EM: You know, so from a sensors

and actuators standpoint,

it's certainly been demonstrated by many

that it's possible to make

a humanoid robot.

The things that are currently missing

are enough intelligence

for the robot to navigate the real world

and do useful things

without being explicitly instructed.

So the missing things are basically

real-world intelligence

and scaling up manufacturing.

Those are two things

that Tesla is very good at.

And so then we basically just need

to design the specialized actuators

and sensors that are needed

for humanoid robot.

People have no idea,

this is going to be bigger than the car.

CA: So let's dig into exactly that.

I mean, in one way, it's actually

an easier problem than full self-driving

because instead of an object

going along at 60 miles an hour,

which if it gets it wrong,

someone will die.

This is an object that's engineered

to only go at what,

three or four or five miles an hour.

And so a mistake,

there aren't lives at stake.

There might be embarrassment at stake.

EM: So long as the AI doesn't take it over

and murder us in our sleep or something.

CA: Right.

(Laughter)

So talk about --

I think the first applications

you've mentioned

are probably going to be manufacturing,

but eventually the vision is to have

these available for people at home.

If you had a robot that really understood

the 3D architecture of your house

and knew where every object

in that house was

or was supposed to be,

and could recognize all those objects,

I mean, that’s kind of amazing, isn’t it?

Like the kind of thing

that you could ask a robot to do

would be what?

Like, tidy up?

EM: Yeah, absolutely.

Make dinner, I guess, mow the lawn.

CA: Take a cup of tea to grandma

and show her family pictures.

EM: Exactly. Take care

of my grandmother and make sure --

CA: It could obviously recognize

everyone in the home.

It could play catch with your kids.

EM: Yes. I mean, obviously,

we need to be careful

this doesn't become a dystopian situation.

I think one of the things

that's going to be important

is to have a localized

ROM chip on the robot

that cannot be updated over the air.

Where if you, for example, were to say,

“Stop, stop, stop,”

if anyone said that,

then the robot would stop,

you know, type of thing.

And that's not updatable remotely.

I think it's going to be important

to have safety features like that.

CA: Yeah, that sounds wise.

EM: And I do think there should be

a regulatory agency for AI.

I've said that for many years.

I don't love being regulated,

but I think this is an important

thing for public safety.

CA: Let's come back to that.

But I don't think many people

have really sort of taken seriously

the notion of, you know, a robot at home.

I mean, at the start

of the computing revolution,

Bill Gates said there's going to be

a computer in every home.

And people at the time said, yeah,

whatever, who would even want that.

Do you think there will be basically

like in, say, 2050 or whatever,

like a robot in most homes,

is what there will be,

and people will love them

and count on them?

You’ll have your own butler basically.

EM: Yeah, you'll have your sort of

buddy robot probably, yeah.

CA: I mean, how much of a buddy?

How many applications have you thought,

you know, can you have

a romantic partner, a sex partner?

EM: It's probably inevitable.

I mean, I did promise the internet

that I’d make catgirls.

We could make a robot catgirl.

CA: Be careful what

you promise the internet.

(Laughter)

EM: So, yeah, I guess it'll be

whatever people want really, you know.

CA: What sort of timeline

should we be thinking about

of the first models

that are actually made and sold?

EM: Well, you know, the first units

that we intend to make

are for jobs that are dangerous,

boring, repetitive,

and things that people don't want to do.

And, you know, I think we’ll have like

an interesting prototype

sometime this year.

We might have something useful next year,

but I think quite likely

within at least two years.

And then we'll see

rapid growth year over year

of the usefulness

of the humanoid robots

and decrease in cost

and scaling up production.

CA: Initially just selling to businesses,

or when do you picture

you'll start selling them

where you can buy your parents one

for Christmas or something?

EM: I'd say in less than ten years.

CA: Help me on the economics of this.

So what do you picture the cost

of one of these being?

EM: Well, I think the cost is actually

not going to be crazy high.

Like less than a car.

Initially, things will be expensive

because it'll be a new technology

at low production volume.

The complexity and cost of a car

is greater than that of a humanoid robot.

So I would expect that it's going

to be less than a car,

or at least equivalent to a cheap car.

CA: So even if it starts at 50k,

within a few years,

it’s down to 20k or lower or whatever.

And maybe for home

they'll get much cheaper still.

But think about the economics of this.

If you can replace a $30,000,

$40,000-a-year worker,

which you have to pay every year,

with a one-time payment of $25,000

for a robot that can work longer hours,

a pretty rapid replacement

of certain types of jobs.

How worried should

the world be about that?

EM: I wouldn't worry about the sort of,

putting people out of a job thing.

I think we're actually going to have,

and already do have,

a massive shortage of labor.

So I think we will have ...

Not people out of work,

but actually still a shortage

labor even in the future.

But this really will be

a world of abundance.

Any goods and services will be available

to anyone who wants them.

It'll be so cheap to have goods

and services, it will be ridiculous.

CA: I'm presuming it should be possible

to imagine a bunch of goods and services

that can't profitably be made now

but could be made in that world,

courtesy of legions of robots.

EM: Yeah.

It will be a world of abundance.

The only scarcity

that will exist in the future

is that which we decide to create

ourselves as humans.

CA: OK.

So AI is allowing us to imagine

a differently powered economy

that will create this abundance.

What are you most worried

about going wrong?

EM: Well, like I said,

AI and robotics will bring out

what might be termed the age of abundance.

Other people have used this word,

and that this is my prediction:

it will be an age of abundance

for everyone.

But I guess there’s ...

The dangers would be

the artificial general intelligence

or digital superintelligence decouples

from a collective human will

and goes in the direction

that for some reason we don't like.

Whatever direction it might go.

You know, that’s sort of

the idea behind Neuralink,

is to try to more tightly couple

collective human world

to digital superintelligence.

And also along the way solve a lot

of brain injuries and spinal injuries

and that kind of thing.

So even if it doesn't succeed

in the greater goal,

I think it will succeed in the goal

of alleviating brain and spine damage.

CA: So the spirit there is

that if we're going to make these AIs

that are so vastly intelligent,

we ought to be wired directly to them

so that we ourselves can have

those superpowers more directly.

But that doesn't seem to avoid

the risk that those superpowers might ...

turn ugly in unintended ways.

EM: I think it's a risk, I agree.

I'm not saying that I have

some certain answer to that risk.

I’m just saying like

maybe one of the things

that would be good

for ensuring that the future

is one that we want

is to more tightly couple

the collective human world

to digital intelligence.

The issue that we face here

is that we are already a cyborg,

if you think about it.

The computers are

an extension of ourselves.

And when we die, we have,

like, a digital ghost.

You know, all of our text messages

and social media, emails.

And it's quite eerie actually,

when someone dies but everything

online is still there.

But you say like, what's the limitation?

What is it that inhibits

a human-machine symbiosis?

It's the data rate.

When you communicate,

especially with a phone,

you're moving your thumbs very slowly.

So you're like moving

your two little meat sticks

at a rate that’s maybe 10 bits per second,

optimistically, 100 bits per second.

And computers are communicating

at the gigabyte level and beyond.

CA: Have you seen evidence

that the technology is actually working,

that you've got a richer, sort of,

higher bandwidth connection, if you like,

between like external

electronics and a brain

than has been possible before?

EM: Yeah.

I mean, the fundamental principles

of reading neurons,

sort of doing read-write on neurons

with tiny electrodes,

have been demonstrated for decades.

So it's not like the concept is new.

The problem is that there is

no product that works well

that you can go and buy.

So it's all sort of, in research labs.

And it's like some cords

sticking out of your head.

And it's quite gruesome,

and it's really ...

There's no good product

that actually does a good job

and is high-bandwidth and safe

and something actually that you could buy

and would want to buy.

But the way to think

of the Neuralink device

is kind of like a Fitbit

or an Apple Watch.

That's where we take out

sort of a small section of skull

about the size of a quarter,

replace that with what,

in many ways really is very much like

a Fitbit, Apple Watch

or some kind of smart watch thing.

But with tiny, tiny wires,

very, very tiny wires.

Wires so tiny, it’s hard to even see them.

And it's very important

to have very tiny wires

so that when they’re implanted,

they don’t damage the brain.

CA: How far are you from putting

these into humans?

EM: Well, we have put in

our FDA application

to aspirationally do the first

human implant this year.

CA: The first uses will be

for neurological injuries

of different kinds.

But rolling the clock forward

and imagining when people

are actually using these

for their own enhancement, let's say,

and for the enhancement of the world,

how clear are you in your mind

as to what it will feel like

to have one of these inside your head?

EM: Well, I do want to emphasize

we're at an early stage.

And so it really will be

many years before we have

anything approximating

a high-bandwidth neural interface

that allows for AI-human symbiosis.

For many years, we will just be solving

brain injuries and spinal injuries.

For probably a decade.

This is not something

that will suddenly one day

it will have this incredible

sort of whole brain interface.

It's going to be, like I said,

at least a decade of really

just solving brain injuries

and spinal injuries.

And really, I think you can solve

a very wide range of brain injuries,

including severe depression,

morbid obesity, sleep,

potentially schizophrenia,

like, a lot of things that cause

great stress to people.

Restoring memory in older people.

CA: If you can pull that off,

that's the app I will sign up for.

EM: Absolutely.

CA: Please hurry. (Laughs)

EM: I mean, the emails that we get

at Neuralink are heartbreaking.

I mean, they'll send us

just tragic, you know,

where someone was sort of,

in the prime of life

and they had an accident on a motorcycle

and someone who's 25, you know,

can't even feed themselves.

And this is something we could fix.

CA: But you have said that AI is one

of the things you're most worried about

and that Neuralink may be one of the ways

where we can keep abreast of it.

EM: Yeah, there's the short-term thing,

which I think is helpful on an individual

human level with injuries.

And then the long-term thing is an attempt

to address the civilizational risk of AI

by bringing digital intelligence

and biological intelligence

closer together.

I mean, if you think of how

the brain works today,

there are really two layers to the brain.

There's the limbic system and the cortex.

You've got the kind of,

animal brain where --

it’s kind of like the fun part, really.

CA: It's where most of Twitter

operates, by the way.

EM: I think Tim Urban said,

we’re like somebody, you know,

stuck a computer on a monkey.

You know, so we're like,

if you gave a monkey a computer,

that's our cortex.

But we still have a lot

of monkey instincts.

Which we then try to rationalize

as, no, it's not a monkey instinct.

It’s something more important than that.

But it's often just really

a monkey instinct.

We're just monkeys with a computer

stuck in our brain.

But even though the cortex

is sort of the smart,

or the intelligent part of the brain,

the thinking part of the brain,

I've not yet met anyone

who wants to delete their limbic system

or their cortex.

They're quite happy having both.

Everyone wants both parts of their brain.

And people really want their

phones and their computers,

which are really the tertiary,

the third part of your intelligence.

It's just that it's ...

Like the bandwidth,

the rate of communication

with that tertiary layer is slow.

And it's just a very tiny straw

to this tertiary layer.

And we want to make that tiny

straw a big highway.

And I’m definitely not saying

that this is going to solve everything.

Or this is you know,

it’s the only thing --

it’s something that might be helpful.

And worst-case scenario,

I think we solve

some important brain injury,

spinal injury issues,

and that's still a great outcome.

CA: Best-case scenario,

we may discover new

human possibility, telepathy,

you've spoken of, in a way,

a connection with a loved one, you know,

full memory and much faster

thought processing maybe.

All these things.

It's very cool.

If AI were to take down Earth,

we need a plan B.

Let's shift our attention to space.

We spoke last time at TED

about reusability,

and you had just demonstrated that

spectacularly for the first time.

Since then, you've gone on to build

this monster rocket, Starship,

which kind of changes the rules

of the game in spectacular ways.

Tell us about Starship.

EM: Starship is extremely fundamental.

So the holy grail of rocketry

or space transport

is full and rapid reusability.

This has never been achieved.

The closest that anything has come

is our Falcon 9 rocket,

where we are able to recover

the first stage, the boost stage,

which is probably about 60 percent

of the cost of the vehicle

of the whole launch, maybe 70 percent.

And we've now done that

over a hundred times.

So with Starship, we will be

recovering the entire thing.

Or at least that's the goal.

CA: Right.

EM: And moreover,

recovering it in such a way

that it can be immediately re-flown.

Whereas with Falcon 9, we still need

to do some amount of refurbishment

to the booster and

to the fairing nose cone.

But with Starship, the design goal

is immediate re-flight.

So you just refill

propellants and go again.

And this is gigantic.

Just as it would be

in any other mode of transport.

CA: And the main design

is to basically take

100 plus people at a time,

plus a bunch of things

that they need, to Mars.

So, first of all, talk about that piece.

What is your latest timeline?

One, for the first time,

a Starship goes to Mars,

presumably without people,

but just equipment.

Two, with people.

Three, there’s sort of,

OK, 100 people at a time, let's go.

EM: Sure.

And just to put the cost

thing into perspective,

the expected cost of Starship,

putting 100 tons into orbit,

is significantly less

than what it would have cost

or what it did cost to put our tiny

Falcon 1 rocket into orbit.

Just as the cost of flying

a 747 around the world

is less than the cost of a small airplane.

You know, a small airplane

that was thrown away.

So it's really pretty mind-boggling

that the giant thing costs less,

way less than the small thing.

So it doesn't use exotic propellants

or things that are difficult

to obtain on Mars.

It uses methane as fuel,

and it's primarily oxygen,

roughly 77-78 percent oxygen by weight.

And Mars has a CO2 atmosphere

and has water ice,

which is CO2 plus H2O,

so you can make CH4, methane,

and O2, oxygen, on Mars.

CA: Presumably, one of the first tasks

on Mars will be to create a fuel plant

that can create the fuel

for the return trips of many Starships.

EM: Yes.

And actually, it's mostly

going to be oxygen plants,

because it's 78 percent oxygen,

22 percent fuel.

But the fuel is a simple fuel

that is easy to create on Mars.

And in many other parts

of the solar system.

So basically ...

And it's all propulsive landing,

no parachutes,

nothing thrown away.

It has a heat shield that’s capable

of entering on Earth or Mars.

We can even potentially go to Venus.

but you don't want to go there.

(Laughs)

Venus is hell, almost literally.

But you could ...

It's a generalized method of transport

to anywhere in the solar system,

because the point at which

you have propellant depo on Mars,

you can then travel to the asteroid belt

and to the moons of Jupiter and Saturn

and ultimately anywhere

in the solar system.

CA: But your main focus

and SpaceX's main focus is still Mars.

That is the mission.

That is where most of the effort will go?

Or are you actually imagining

a much broader array of uses

even in the coming, you know,

the first decade or so of uses of this.

Where we could go,

for example, to other places

in the solar system to explore,

perhaps NASA wants to use

the rocket for that reason.

EM: Yeah, NASA is planning to use

a Starship to return to the moon,

to return people to the moon.

And so we're very honored that NASA

has chosen us to do this.

But I'm saying it is a generalized --

it’s a general solution

to getting anywhere

in the greater solar system.

It's not suitable for going

to another star system,

but it is a general solution for transport

anywhere in the solar system.

CA: Before it can do any of that,

it's got to demonstrate it can get into

orbit, you know, around Earth.

What’s your latest advice

on the timeline for that?

EM: It's looking promising for us

to have an orbital launch attempt

in a few months.

So we're actually integrating --

will be integrating the engines

into the booster

for the first orbital flight

starting in about a week or two.

And the launch complex

itself is ready to go.

So assuming we get regulatory approval,

I think we could have an orbital

launch attempt within a few months.

CA: And a radical new technology like this

presumably there is real risk

on those early attempts.

EM: Oh, 100 percent, yeah.

The joke I make all the time

is that excitement is guaranteed.

Success is not guaranteed,

but excitement certainly is.

CA: But the last I saw on your timeline,

you've slightly put back the expected date

to put the first human on Mars

till 2029, I want to say?

EM: Yeah, I mean, so let's see.

I mean, we have built a production

system for Starship,

so we're making a lot

of ships and boosters.

CA: How many are you planning

to make actually?

EM: Well, we're currently expecting

to make a booster and a ship

roughly every, well, initially,

roughly every couple of months,

and then hopefully by the end

of this year, one every month.

So it's giant rockets, and a lot of them.

Just talking in terms

of rough orders of magnitude,

in order to create

a self-sustaining city on Mars,

I think you will need something

on the order of a thousand ships.

And we just need a Helen of Sparta,

I guess, on Mars.

CA: This is not in most

people's heads, Elon.

EM: The planet that launched 1,000 ships.

CA: That's nice.

But this is not in most people's heads,

this picture that you have in your mind.

There's basically a two-year window,

you can only really fly to Mars

conveniently every two years.

You were picturing that during the 2030s,

every couple of years,

something like 1,000 Starships take off,

each containing 100 or more people.

That picture is just completely

mind-blowing to me.

That sense of this armada

of humans going to --

EM: It'll be like "Battlestar

Galactica," the fleet departs.

CA: And you think that it can

basically be funded by people

spending maybe a couple hundred grand

on a ticket to Mars?

Is that price about where it has been?

EM: Well, I think if you say like,

what's required in order to get

enough people and enough cargo to Mars

to build a self-sustaining city.

And it's where you have an intersection

of sets of people who want to go,

because I think only a small percentage

of humanity will want to go,

and can afford to go

or get sponsorship in some manner.

That intersection of sets, I think,

needs to be a million people

or something like that.

And so it’s what can a million people

afford, or get sponsorship for,

because I think governments

will also pay for it,

and people can take out loans.

But I think at the point

at which you say, OK, like,

if moving to Mars costs are,

for argument’s sake, $100,000,

then I think you know,

almost anyone can work and save up

and eventually have $100,000

and be able to go to Mars if they want.

We want to make it available

to anyone who wants to go.

It's very important to emphasize

that Mars, especially in the beginning,

will not be luxurious.

It will be dangerous, cramped,

difficult, hard work.

It's kind of like that Shackleton ad

for going to the Antarctic,

which I think is actually not real,

but it sounds real and it's cool.

It's sort of like, the sales pitch

for going to Mars is,

"It's dangerous, it's cramped.

You might not make it back.

It's difficult, it's hard work."

That's the sales pitch.

CA: Right.

But you will make history.

EM: But it'll be glorious.

CA: So on that kind of launch rate

you're talking about over two decades,

you could get your million people

to Mars, essentially.

Whose city is it?

Is it NASA's city, is it SpaceX's city?

EM: It’s the people of Mars’ city.

The reason for this, I mean,

I feel like why do this thing?

I think this is important for maximizing

the probable lifespan of humanity

or consciousness.

Human civilization could come

to an end for external reasons,

like a giant meteor or super volcanoes

or extreme climate change.

Or World War III, or you know,

any one of a number of reasons.

But the probable life span

of civilizational consciousness

as we know it,

which we should really view

as this very delicate thing,

like a small candle in a vast darkness.

That is what appears to be the case.

We're in this vast darkness of space,

and there's this little

candle of consciousness

that’s only really come about

after 4.5 billion years,

and it could just go out.

CA: I think that's powerful,

and I think a lot of people

will be inspired by that vision.

And the reason you need the million people

is because there has to be

enough people there

to do everything that you need to survive.

EM: Really, like the critical threshold

is if the ships from Earth stop coming

for any reason,

does the Mars City die out or not?

And so we have to --

You know, people talk about like,

the sort of, the great filters,

the things that perhaps, you know,

we talk about the Fermi paradox,

and where are the aliens?

Well maybe there are these

various great filters

that the aliens didn’t pass,

and so they eventually

just ceased to exist.

And one of the great filters

is becoming a multi-planet species.

So we want to pass that filter.

And I'll be long-dead before

this is, you know, a real thing,

before it happens.

But I’d like to at least see us make

great progress in this direction.

CA: Given how tortured

the Earth is right now,

how much we're beating each other up,

shouldn't there be discussions going on

with everyone who is dreaming

about Mars to try to say,

we've got a once

in a civilization's chance

to make some new rules here?

Should someone be trying

to lead those discussions

to figure out what it means for this

to be the people of Mars' City?

EM: Well, I think ultimately

this will be up to the people

of Mars to decide

how they want to rethink society.

Yeah there’s certainly risk there.

And hopefully the people of Mars

will be more enlightened

and will not fight

amongst each other too much.

I mean, I have some recommendations,

which people of Mars

may choose to listen to or not.

I would advocate for more

of a direct democracy,

not a representative democracy,

and laws that are short enough

for people to understand.

Where it is harder to create laws

than to get rid of them.

CA: Coming back a bit nearer term,

I'd love you to just talk a bit

about some of the other possibility space

that Starship seems to have created.

So given --

Suddenly we've got this ability

to move 100 tons-plus into orbit.

So we've just launched

the James Webb telescope,

which is an incredible thing.

It's unbelievable.

EM: Exquisite piece of technology.

CA: Exquisite piece of technology.

But people spent two years trying

to figure out how to fold up this thing.

It's a three-ton telescope.

EM: We can make it a lot easier

if you’ve got more volume and mass.

CA: But let's ask a different question.

Which is, how much more powerful

a telescope could someone design

based on using Starship, for example?

EM: I mean, roughly, I'd say it's probably

an order of magnitude more resolution.

If you've got 100 tons

and a thousand cubic meters volume,

which is roughly what we have.

CA: And what about other exploration

through the solar system?

I mean, I'm you know --

EM: Europa is a big question mark.

CA: Right, so there's an ocean there.

And what you really want to do

is to drop a submarine into that ocean.

EM: Maybe there's like,

some squid civilization,

cephalopod civilization

under the ice of Europa.

That would be pretty interesting.

CA: I mean, Elon, if you could take

a submarine to Europa

and we see pictures of this thing

being devoured by a squid,

that would honestly be

the happiest moment of my life.

EM: Pretty wild, yeah.

CA: What other possibilities

are out there?

Like, it feels like if you're going to

create a thousand of these things,

they can only fly to Mars every two years.

What are they doing the rest of the time?

It feels like there's this

explosion of possibility

that I don't think people

are really thinking about.

EM: I don't know, we've certainly

got a long way to go.

As you alluded to earlier,

we still have to get to orbit.

And then after we get to orbit,

we have to really prove out and refine

full and rapid reusability.

That'll take a moment.

But I do think we will solve this.

I'm highly confident

we will solve this at this point.

CA: Do you ever wake up with the fear

that there's going to be this

Hindenburg moment for SpaceX where ...

EM: We've had many Hindenburg.

Well, we've never had Hindenburg moments

with people, which is very important.

Big difference.

We've blown up quite a few rockets.

So there's a whole compilation online

that we put together

and others put together,

it's showing rockets are hard.

I mean, the sheer amount of energy

going through a rocket boggles the mind.

So, you know, getting out

of Earth's gravity well is difficult.

We have a strong gravity

and a thick atmosphere.

And Mars, which is less than 40 percent,

it's like, 37 percent of Earth's gravity

and has a thin atmosphere.

The ship alone can go all the way

from the surface of Mars

to the surface of Earth.

Whereas getting to Mars requires

a giant booster and orbital refilling.

CA: So, Elon, as I think more

about this incredible array of things

that you're involved with,

I keep seeing these synergies,

to use a horrible word,

between them.

You know, for example,

the robots you're building from Tesla

could possibly be pretty handy on Mars,

doing some of the dangerous

work and so forth.

I mean, maybe there's a scenario

where your city on Mars

doesn't need a million people,

it needs half a million people

and half a million robots.

And that's a possibility.

Maybe The Boring Company could play a role

helping create some of the subterranean

dwelling spaces that you might need.

EM: Yeah.

CA: Back on planet Earth,

it seems like a partnership

between Boring Company and Tesla

could offer an unbelievable deal to a city

to say, we will create for you

a 3D network of tunnels

populated by robo-taxis

that will offer fast, low-cost

transport to anyone.

You know, full self-driving may

or may not be done this year.

And in some cities,

like, somewhere like Mumbai,

I suspect won't be done for a decade.

EM: Some places are more

challenging than others.

CA: But today, today,

with what you've got,

you could put a 3D network

of tunnels under there.

EM: Oh, if it’s just in a tunnel,

that’s a solved problem.

CA: Exactly, full self-driving

is a solved problem.

To me, there’s amazing synergy there.

With Starship,

you know, Gwynne Shotwell talked

about by 2028 having from city to city,

you know, transport on planet Earth.

EM: This is a real possibility.

The fastest way to get

from one place to another,

if it's a long distance, is a rocket.

It's basically an ICBM.

CA: But it has to land --

Because it's an ICBM,

it has to land probably offshore,

because it's loud.

So why not have a tunnel

that then connects to the city with Tesla?

And Neuralink.

I mean, if you going to go to Mars

having a telepathic connection

with loved ones back home,

even if there's a time delay...

EM: These are not intended

to be connected, by the way.

But there certainly could be

some synergies, yeah.

CA: Surely there is a growing argument

that you should actually put

all these things together

into one company

and just have a company

devoted to creating a future

that’s exciting,

and let a thousand flowers bloom.

Have you been thinking about that?

EM: I mean, it is tricky because Tesla

is a publicly-traded company,

and the investor base of Tesla and SpaceX

and certainly Boring Company

and Neuralink are quite different.

Boring Company and Neuralink

are tiny companies.

CA: By comparison.

EM: Yeah, Tesla's got 110,000 people.

SpaceX I think is around 12,000 people.

Boring Company and Neuralink

are both under 200 people.

So they're little, tiny companies,

but they will probably

get bigger in the future.

They will get bigger in the future.

It's not that easy to sort

of combine these things.

CA: Traditionally, you have said

that for SpaceX especially,

you wouldn't want it public,

because public investors wouldn't support

the craziness of the idea

of going to Mars or whatever.

EM: Yeah, making life multi-planetary

is outside of the normal time horizon

of Wall Street analysts.

(Laughs)

To say the least.

CA: I think something's changed, though.

What's changed is that Tesla is now

so powerful and so big

and throws off so much cash

that you actually could

connect the dots here.

Just tell the public that x-billion

dollars a year, whatever your number is,

will be diverted to the Mars mission.

I suspect you'd have massive

interest in that company.

And it might unlock a lot

more possibility for you, no?

EM: I would like to give the public access

to ownership of SpaceX,

but I mean the thing that like,

the overhead associated

with a public company is high.

I mean, as a public company,

you're just constantly sued.

It does occupy like, a fair bit of ...

You know, time and effort

to deal with these things.

CA: But you would still only have one

public company, it would be bigger,

and have more things going on.

But instead of being

on four boards, you'd be on one.

EM: I'm actually not even on the Neuralink

or Boring Company boards.

And I don't really attend

the SpaceX board meetings.

We only have two a year,

and I just stop by and chat for an hour.

The board overhead for a public

company is much higher.

CA: I think some investors probably worry

about how your time is being split,

and they might be excited

by you know, that.

Anyway, I just woke up the other day

thinking, just, there are so many ways

in which these things connect.

And you know,

just the simplicity of that mission,

of building a future that is worth

getting excited about,

might appeal to an awful lot of people.

Elon, you are reported by Forbes

and everyone else as now, you know,

the world's richest person.

EM: That’s not a sovereign.

CA: (Laughs)

EM: You know, I think it’s fair to say

that if somebody is like, the king

or de facto king of a country,

they're wealthier than I am.

CA: But it’s just harder to measure --

So $300 billion.

I mean, your net worth on any given day

is rising or falling

by several billion dollars.

How insane is that?

EM: It's bonkers, yeah.

CA: I mean, how do you handle

that psychologically?

There aren't many people in the world

who have to even think about that.

EM: I actually don't think

about that too much.

But the thing that is

actually more difficult

and that does make sleeping difficult

is that, you know,

every good hour or even minute

of thinking about Tesla and SpaceX

has such a big effect on the company

that I really try to work

as much as possible,

you know, to the edge

of sanity, basically.

Because you know,

Tesla’s getting to the point where

probably will get

to the point later this year,

where every high-quality

minute of thinking

is a million dollars impact on Tesla.

Which is insane.

I mean, the basic, you know,

if Tesla is doing, you know,

sort of $2 billion a week,

let’s say, in revenue,

it’s sort of $300 million a day,

seven days a week.

You know, it's ...

CA: If you can change that by five percent

in an hour’s brainstorm,

that's a pretty valuable hour.

EM: I mean, there are many instances

where a half-hour meeting,

I was able to improve

the financial outcome of the company

by $100 million

in a half-hour meeting.

CA: There are many other people out there

who can't stand

this world of billionaires.

Like, they are hugely

offended by the notion

that an individual can have

the same wealth as, say,

a billion or more

of the world's poorest people.

EM: If they examine sort of --

I think there's some axiomatic flaws

that are leading them to that conclusion.

For sure, it would be very

problematic if I was consuming,

you know, billions of dollars a year

in personal consumption.

But that is not the case.

In fact, I don't even own

a home right now.

I'm literally staying at friends' places.

If I travel to the Bay Area,

which is where most

of Tesla engineering is,

I basically rotate through

friends' spare bedrooms.

I don't have a yacht,

I really don't take vacations.

It’s not as though my personal

consumption is high.

I mean, the one exception is a plane.

But if I don't use the plane,

then I have less hours to work.

CA: I mean, I personally think

you have shown that you are mostly driven

by really quite a deep

sense of moral purpose.

Like, your attempts to solve

the climate problem

have been as powerful as anyone else

on the planet that I'm aware of.

And I actually can't understand,

personally, I can't understand the fact

that you get all this criticism

from the Left about,

"Oh, my God, he's so rich,

that's disgusting."

When climate is their issue.

Philanthropy is a topic

that some people go to.

Philanthropy is a hard topic.

How do you think about that?

EM: I think if you care

about the reality of goodness

instead of the perception of it,

philanthropy is extremely difficult.

SpaceX, Tesla, Neuralink

and The Boring Company are philanthropy.

If you say philanthropy

is love of humanity,

they are philanthropy.

Tesla is accelerating sustainable energy.

This is a love -- philanthropy.

SpaceX is trying to ensure

the long-term survival of humanity

with a multiple-planet species.

That is love of humanity.

You know, Neuralink is trying to help

solve brain injuries

and existential risk with AI.

Love of humanity.

Boring Company is trying to solve traffic,

which is hell for most people,

and that also is love of humanity.

CA: How upsetting is it to you

to hear this constant drumbeat of,

"Billionaires, my God,

Elon Musk, oh, my God?"

Like, do you just shrug that off

or does it does it actually hurt?

EM: I mean, at this point,

it's water off a duck's back.

CA: Elon, I’d like to,

as we wrap up now,

just pull the camera back

and just think ...

You’re a father now

of seven surviving kids.

EM: Well, I mean, I'm trying

to set a good example

because the birthrate on Earth is so low

that we're facing civilizational collapse

unless the birth rate returns

to a sustainable level.

CA: Yeah, you've talked about this a lot,

that depopulation is a big problem,

and people don't understand

how big a problem it is.

EM: Population collapse

is one of the biggest threats

to the future of human civilization.

And that is what is going on right now.

CA: What drives you on a day-to-day

basis to do what you do?

EM: I guess, like,

I really want to make sure

that there is a good future for humanity

and that we're on a path to understanding

the nature of the universe,

the meaning of life.

Why are we here, how did we get here?

And in order to understand

the nature of the universe

and all these fundamental questions,

we must expand the scope

and scale of consciousness.

Certainly it must not diminish or go out.

Or we certainly won’t understand this.

I would say I’ve been motivated

by curiosity more than anything,

and just desire to think about the future

and not be sad, you know?

CA: And are you?

Are you not sad?

EM: I'm sometimes sad,

but mostly I'm feeling I guess

relatively optimistic

about the future these days.

There are certainly some big

risks that humanity faces.

I think the population collapse

is a really big deal,

that I wish more people would think about

because the birth rate is far below

what's needed to sustain civilization

at its current level.

And there's obviously ...

We need to take action

on climate sustainability,

which is being done.

And we need to secure

the future of consciousness

by being a multi-planet species.

We need to address --

Essentially, it's important to take

whatever actions we can think of

to address the existential risks

that affect the future of consciousness.

CA: There's a whole

generation coming through

who seem really sad about the future.

What would you say to them?

EM: Well, I think if you want the future

to be good, you must make it so.

Take action to make it good.

And it will be.

CA: Elon, thank you for all this time.

That is a beautiful place to end.

Thanks for all you're doing.

EM: You're welcome.