-Begin Transcript-

Today we're reaching into the vault to bring you a lecture delivered to the NSA workforce in 1982 by then-Navy Captain Grace Hopper entitled, "Future Possibilities: Data, Hardware, Software, and People."

Grace Hopper was an American computer scientist and mathematician, and a pioneer of computer programing.

Among her accomplishments, Hopper was the first to devise the theory of machine-independent programming languages.

She ultimately reached the rank of Rear Admiral in the United States Navy, and in 2016 she was posthumously awarded the Presidential Medal of Freedom - the nation's highest civilian honor.

Her insights on leadership and her visionary predictions still hold weight today, more than forty years later.

And there is a reason why I like that introduction. It s because it gives me an opportunity to remind you that the first large scale digital computer in the United States was

a Navy computer, operated by Navy crew during World War Two. And recently I ve been finding

that I have to remind people that, because it s been a tendency on the part of a certain junior

service to try and claim credit for those early computers. And they didn t even exist

And they didn t even exist yet -- So --

Please remember that it was a Navy computer -- And if you re wondering why I kept my cap on,

I had a reason for that too, it s because this is my identifier -- I hope you all know by now that every

record in a computer system must have an identifier. That s so you know where to put it and how to get it again. -- There s something odd about those identifiers,

though; they have to be understood both by the person that originally puts it on the record and the person who later looks at the record -- [TIME: 00:01:46]

That s why my problem has been -- I go wandering around airports and people come up to me and say, "When s the next plane leave for Houston?"

I got totally demoted one night and print San Francisco. I got off an elevator and

there was a couple in the elevator with me -- As I got off, I heard the woman said her husband. "What was that?" -- You have heard the worst of it, and he

said "that was a security guard" -- So --

Then I went up to Canada to speak at the University of Guelph and I had to go through immigration at the Toronto airport. So I handed my passport to

the immigration officer and ...an officer and he looked at it and looked at me and said, "What are you?" And I said, "United States Navy."

He took a second real hard look at me and then he said you must be the oldest one they ve got.

You know, um, I didn t really feel that was a polite way to welcome visitors to Canada.

[TIME: 00:02:50] But the only put me down I could think of was to say no, Admiral Rickover is six years older. And I don t think he even knew who

Admiral Rickover was. But if you know what... But if you know what I am I ll take my cap off. That only goes to show my white hair.

Actually, I can remember when Riverside Drive in New York City along the Hudson River was a

dirt road. And on Sunday afternoons, as a family, we would go out and sit on the drive and watch all the beautiful horses and carriages go by. In a whole afternoon,

there might be one car; cars were enormously expensive. They were individually built --

There was no such thing as gas stations if you went on a long trip you ve got five gallon cans of gasoline, put them on the back deck, strap them the car and took your gasoline with you.

If you broke down in the middle of Utah, you wired back to the manufacture, and then he sent a man out with a part and he worked on the part til it fitted your car.

And along came a gentleman named Henry Ford with two concepts: standard interchangeable parts and an assembly line, and he started to build Model Ts.

I think we ve totally forgotten how tremendously that changed the world -- You could have any color you

wanted as long as it was black -- They cost between three hundred and six hundred

dollars and people started to own cars -- Naturally, had once they had cars,

they demanded roads, we built them. Gas stations appeared, garages were stocked

with interchangeable parts, they appeared -- People found they could move to suburbs and drive to work -- And then of course they wanted to shop near home,

so we had to build shopping centers -- I think we ve forgotten the tremendous developments that followed from the Model T Ford --

Now, whether you recognize it or not -- The Model Ts of the computer industry

are here. We ve been through the preliminaries of the industry --

We re now at the beginning of what will be the largest industry in the United States,

and I m quite worried about something. When we built all those roads and the shopping centers

and all the other things, and provided for automobile transportation, transportation,

we forgot something. We forgot transportation as a whole. We only looked at the automobiles.

Because of that, today, when we need them again, the road beds, the railroads are falling apart -- [TIME: 00:05:23] A dumping polygon

clear right around the countryside -- If we wanted to move our tanks from the center of the country to the ports to shipped them overseas,

there are no flat cars left because we move all the cars on those racks on the roads now.

If we wanted to move coal to replace oil, they re, probably not enough hopper cars to move both the grain crop and the coal -- And the truth of the matter is we ve done a lousy

job of managing transportation as a whole. -- Now, as we come to the world of the micro

computer, I think we re going to be facing the same possibility. I m afraid we will continue to buy pieces of

hardware and then put programs on them, when what we should be doing is looking at the underlying

thing, which is the total flow of information -- -- to any organization, activity, company,

or what have you. We should be looking at the information flow, and then selecting the computers

to implement that information flow. [TIME: 00:06:24] Now, of course, if we do that, one of the first things we ll need to know is something about

the value of the information we re processing. It s close to 8 years now that I ve been trying

to ask people how they value their information -- I ve gotten the finest assortment of blank stares

you ever saw in your entire life -- I even question whether there was a

difference. Naively, I thought I could find out how people were evaluating their information if

I could find out how priorities were assigned on the computer systems. Boy, did that go flat fast!

I found out exactly how the priorities are assigned. Top priority already goes to the senior squeaky wheel, not to the most valuable information. Some people even questioned

that there was a difference in the value of information. I use as an example chemical plant --

I know up in Michigan that s totally operated by computer. Information comes in from Marketing,

goes through the computer; it opens valves, pushes stuff through pipes, tells Inventory what it s made; the people are paid by the computer; nice computerized reports go up to the president s desk. Now, let s suppose that two pieces of information under that flow simultaneously from

two different ports in the system. One comes from a valve out in the plant and says, "If you don t open me, the plant s going to blow up -- [TIME: 00:07:39]

You have less than a minute in which to act; a hundred lives at stake, hundred million dollar chemical plant. At the same instant, in another part of the system, comes the fact that Joe did

2 hours of overtime. Which is the more valuable piece of information? And what are our criteria?

I ve mentioned three possible criteria. The time in which we have to act; the number of lives

affected; the number of dollars affected. I think there s a fourth: the importance of that piece of information in making decisions. No work -- no research has been done on

the value of information. We ve completely failed to look at it and yet it s going to make a tremendous difference in how we run our computer systems of the future.

Cause there are two things that are dead sure; I don t even have to call them predictions. One is that the amount of data and the amount of information will continue to increase,

and it s more than linear. And the other is the demand for instant access to that information will increase. And those two are in conflict. We ve got to know something about the value of

the information being processed -- [TIME: 00:08:43] Everybody wants our information online. If one department gets an online system than all

the other departments want an online system. In many cases, that s a matter of prestige, not of actual need, and I played a very mean trick on one activity. I tacked counter on every record.

Every time the record was looked at I added one -- At the end of six months, I printed out everything which had not been looked at -- One entire file fell out,

yet the owner of that data had insisted that his information must be online.

It was a matter of prestige to have his information online, not that he really needed it there. One outfit has taken a second, a second

look at the data from that point of view -- it s the Coast Guard. They had a file which contained the complete history of every buoy. And when

a ship went out to maintain the buoys -- They d look in the file to see what had been done about the buoy over the last couple of years and whether

any message have been left to look at something next time. [TIME: 00:09:43] Those records started years ago,

as a punch card and they d gotten longer and longer and longer and longer over the years. The whole system was slowing down, and yet they needed rapid access to it.

So take a second look at those records, and they said, hey, we don t need that whole record on line. All we want online, is the last couple of years.

We don t need to know when we bought the buoy and how much it cost unless we re going in for a budget to get a new buoy. We can have that answer tomorrow or the next day. They chopped

those records. The front end of it that they need for reference to go out and maintain the buoy is online. The rest of the record is going back to batch and you can have the answer

tomorrow or the next day. Somewhat the same thing has been done by Tactical Air Command at Langley.

They were carrying online, for assignment on base, the complete record and history of every person --

The whole system was slowing down because the records were so long. So the took a second look at the records and they said hey we don t need that whole record when we

re assigning a men on base. All we need to know is the last couple of schools he s been to and the

last couple of assignments he s had. [TIME: 00:10:50] We don t care where he went to high school -- So they trap the records, the immediate past

history is online, the rest of it s going back to batch and if he s coming up for an award or promotion or something you can have that tomorrow or the next day,

they ve begun to look at least at the time value of the information. There s

been no research in this area, there s no one publishing papers, not even on the relative

value of information within an organization -- Nobody is looking at the value of information

or comparative value of different pieces of information, and we ve got to look at it because

it s cutting up our online systems -- And we ve got to know more about the value of information in order to design the systems of the future.

I thought up a couple of curves. I have no numbers to put on them and research hasn t been done yet -- But at least I think I can

talk about the shape of them. Suppose this is dollars, and this is time --

And an event occurs here. Now the value of the information about that event goes up quite sharply immediately after the event, which

the further you get away from the event in time, the more the value of that information levels off. It goes up very sharply and it levels off. Now ultimately, it either gets replaced by a new

piece of information, or we decide we don t need it online anymore and we transfer to historical

files, microfilm or something like that. Of course, in industry they have to save it for the IRS, so the value curve probably look something like that: a sharp rise,

a leveling off, and then an eventual transfer to some form of historical file.

What about the cost of that information? Cost of information is very, very low at the time of the event, but the further you get away from the event in time,

the more the cost you pile up to start, maintain it, and add any information to it. So the cost

curve starts low and then it goes zooming up -- Now there s a lovely crossover point there -- that

s the point at which keeping that information in our online system is costing us more than it s worth to us. But because we don t know where that point is, we have no way of getting stuff

out of our online systems, and that depends on knowing something of the value and the cost of

the information concerned. We ve got a big job to do in investigating those areas --

As a matter of fact, we don t even know the possible cost of having incorrect information in a system. This vastly

upset Lieutenant Colonel Randleman down at Maxwell Air Force Base and he decided to investigate the

possible cost of having incorrect information in the system. He found a section in the privacy

law. Fortunately most of our government employees don t know it s there or haven t found it yet --

which says that if you have incorrect information in a personnel file, and if because of it,

someone s denied a promotion or a raise or something like that, they have a right to sue the federal government. It s one of the very few cases in which the individual

is directly given the right to sue the federal government and it s a very powerful paragraph.

Whenever any agency fails to maintain any record concerning any individual with such accuracy,

relevance, timeliness, and completeness -- boy, that s four powerful words! -- as is

necessary to assure fairness in any determination relating to the qualifications, character, rights,

opportunities of, or benefits to the individual that may be made on the basis of such record,

and consequently a determination is made which is adverse to the individual — the individual may bring a civil action

against the agency, and the District Courts of the United States shall have jurisdiction in the matters under the provisions of this sub-section. So we decided to find out how much it might cost

to have incorrect information in a personnel file. And he said, let s suppose I have a personnel

file on 8,000 people. And he said further, let s suppose that I know the file is 95% correct -- He

s selected things and looked at em and gotten a -- correctness percentage. Of course, I don t believe there s personnel file in the country that s 95% correct, but he said, let s suppose it is,

and that means that 5% of those records contain incorrect information. Four hundred of em contain

incorrect information. Then he went and talked to the decision making people, and the psychologists,

and so on, and he said, what s going to be the effect of that incorrect information? And they said, well, it s going to stick out; it probably won t match the rest of the file --

Nobody takes any chances on anybody nowadays; we think in 90% of those cases, a negative decision

will be taken on the basis of the incorrect information. That would mean in 360 cases,

a negative decision is taken on the basis of incorrect information. Then he said,

we don t know how many of those people will sue; we have no experience with that yet. So by the laws of probability we ll have to say it s 50-50. 180 up and sue the government --

Now, of course, they re bound win their suit, because the incorrect information s in the file -- So he said, let s suppose the damages

are two thousand dollars -- I think he under estimated that, hundred dollars for court cost six hundred and fifty for lawyers each in those cases is

going to cost us two thousand seven hundred and fifty dollars out of much do we stand to lose because of incorrect information -- Well, it turns out that 180 times 2750 s darn

close to half a million dollars: $495,000, the possible cost of information in that personnel

file. Now until we make that computation of the possible cost of incorrect information,

we can t make a clear estimate of how much we are willing to spend to correct the file -- I now know the economically:

I can go up to almost half a million dollars to get that file to a higher level of correctness, because that s what I stand to lose -- We ve almost never made any computation of the

possible costs of incorrect information in the system. [TIME: 00:17:02] One of the things that bothers me is we talked

about data processing for thirty years, we spend all our time talking about the processing hardware

and software, we paid no attention to the data -- And yet the data is our raw material --

Our output is information, our product -- And we should be concentrating

on the data in the information. The hardware and software are, after all, only the tools which we do the processing and should not occupied the primary position in our thinking.

It s high time, we began to turn our attention -- To the data and the information

that we re putting out -- I don t know how I m going to persuade people to do it, but I ll try hard. There were a lot of things that we re pushing me

toward worrying about all this future business -- We ran the Mark computers all during world war.

Two -- I thought you might like to know that the first computer bug is still in existence -- We were building Mark two the summer of

nineteen forty five. It was a hot summer in Cambridge and naturally, since it was world war two we were working in a world war one temporary building

air conditioning wasn t very good, no screens and Mark two stops we finally located the failing relay.

It was one of the big signal relays and inside the relay beaten to death by the relay contacts was a moth about this big -- So the operator got a pair of tweezers and

very carefully fish the moth out of the relay put it in the log book put Scotch tape over and

below-below it her he wrote. First actual bug found --

I know you ll be glad to know that the bug is still in the log book under the Scotch tape. It s in the museum at the naval surface weapon center in Dahlgren Virginia --

And I ve told that story a lot of times. It turned out some people didn t believe me, particularly American Federation of information processing societies.

So, they made an expedition to Dahlgren and sure enough. They found the first bug in the log book under the Scotch tape, so they took a picture of it

and last year, in the July 1981 issue of the Annuls of the history of computers. They published a picture of the first bug.

And I think it s rather nice that the Navy is keeping a few of the early artifact like the first bug and me in a few other things. -- However it finally got to be 1946

and each one of us had, the war was over, and each one of us had to decide what we were going to do next -- Now up to that time, the WAVES had always

been reservists and in forty six the Navy offered the opportunity to the WAVES to transfer to the regular Navy. So naturally I applied for for transfer

to the regular Navy and I was turned down because I was too old. The cut-off age was thirty-eight, and I was forty, and incidentally,

it s just as well to be told your too old when you re forty, because you go through the traumatic experience and it never bothers you again after that. I really recommend it, highly.

However, I elected to remain in the reserves. Now back in those days, in the reserves, we had three

jobs to do: summer training duty, weekly meetings, and take correspondence courses. We had to take correspondence

courses according to our designators -- I was then an ordinance officer --

At present, thanks to the now defunct naval personnel, it turns out I m an aeronautical engineer, but I don t worry about that. So I took ordinance courses and of course the

Navy was using all using up all the old manuals you ll at the end of the war, so I ve learned all about big guns and gun turrets and everything we within phasing out of the Navy, though it may come

in handy again, I ran out of ordinance courses -- The only other courses that would credit for

my designated with a war college courses so absolutely terrified. I sent for the first war college course and they sent me the first problem --

I was to fuel a task force at sea in minimum time, and all I told me was how fast the

different ships could pump oil and receive oil. And of course I knew nothing about fueling. Ships at sea -- But I had to do

something so I lined up an oiler in the carrier and start pumping from the oiler to the carrier.

Perfectly clear that wasn t going to get me minimum time -- So I decided they must have given me the

rates for some reason I looked at those found. I could simultaneously pump oil to carrier and carrier to destroyer and they d both be filling up because the rates were different --

Now, somewhere along the line, somebody had given me a course in problem-solving and they told me to always extend every solution. So I did I start pumping from the destroyer to a

Corvette. We still had something (laugh) -- That was all working beautifully --

But that course also told me I must generalize every solution -- Show I did on the other side of the oiler, or I pulled up

a cruiser in a destroyer and of Corvette. I ended up with half a task force all hitched up

with lines sailing down the middle of the ocean -- My problem is returned with the comment and

interesting solution -- I just decided that: wasn t a way to fuel ships at sea -- Along came the next problem this time

and gave me a squadron of submarines, told me scout the Caribbean minimum time. Well I knew less about submarines than I did about Oilers. So this time I called on my friendly computer

to help me and I used a random walk program for each of the submarines. You should have seen that map. I covered at minimum time, it was beautiful. Only trouble

was I had those submarines cutting across each other; they made U-turns, one did a little circle up here and came back. An interesting solution --

I was even beginning to feel some sympathy for the poor guy at the war college that had to read my solutions and along came the third one, and that was the important one --

I was to make a plan to take an island -- And after I completed my plan, I was to make two reviews of it. I was to review my plan in the light

of all possible enemy actions, all possible future events, and then I was to review the

cost of not carrying out the plan -- Two reviews which are critical to any

plan whatsoever that I keep finding them left off of our plans for computers --

We have a very bad tendency to base our plans for computers on the equipment we have in house and the things we re doing now.

And totally failed to review them in the light of the equipment that will be available and the things that we will be doing -- I think the saddest praise I ever hear in

a computer installation is that horrible one "but we ve always done it that way."

That s a forbidden phrase in my office -- To emphasize the fact I keep a clock which

operates entirely counterclockwise -- Now the first day people meet it, they can t tell time. By the second day, they discover what used to be 10 of is now 10 after,

they can tell time again. Normally it s not until the third day that they recognize -- That there was never any reason

why clock should run clockwise that could just as well as run counter clockwise --

There s no reason for the hands to go by the digits. I have another clock that has a pointer and the digits go round on a drum. Tells perfectly good

time, course by now I have a digital clock -- [TIME: 00:24:29] And my helpful crew gave me an hour glass -- But they sit there day in and day out and say:

never never, never in this office say, but we ve always done it that way.

Now, when it comes to carousels at airports, I can see a good reason why they run this way. That s because most people are right handed and that s the way you grab your bag.

I still haven t found out why helicopter rotors go the way they do, but --

I find it rather interesting -- "that we ve always done it this way" seems to be so much embedded in things and it s the most dangerous phrase you can

use in a computer installation -- So hopefully, I ll give you each

one of your very small gift. I will promise you something, if during the next 12 months any one of you says, "but we ve always done it that way",

I will instantly materialize beside you and I will haunt you for 24 hours --

And see if I can get you to think again and I know it works, I ve already had over 70 letters thanking me for honing people -- [TIME: 00:25:32]

I ll be there we ve got to accept the new things that are ahead --

One of the major difficulties is the difficulty of changing people s minds -- I had to give a presentation and for the EDP policy committee, the Joint Chiefs of Staff,

all admirals and generals -- I had to remind those gentleman that they ve had piles of big reports sitting on their desk that they d had to read and absorb,

big decisions they had to make and they had not had time to keep up with the technology that was

changing overnight, and therefore they were going to have to learn to listen to their juniors --

I m telling all the youngsters -- officer and enlisted -- and civilian -- Never never never take the first no.

There are a certain number of people, business, industry, government, who always say no the first time you suggest something new, because they re lazy, you know if they say yes they re going to

have to do something about it. But there s another group, who are even more dangerous in a way, who always say no the

first time you suggest something new or different because they want to see if you believe it enough to come back and ask again -- So never take the first "no",

always go back and ask again a matter of fact, I take about four "nos" and then I figure out how to get around the guy, but -- That technique comes with age.

I ran into one of these guys during World War II in Buord. After about two or three suggestions, I noticed he always said "no" to things,

the first time. So the next time I wanted to suggest something, I said: let s pretend this is the second time I m presenting this -- I said you always say "no" the first time and

he looked at me with the funniest expression. I had him over the barrel from then on because I just go and say this is the fourth time I m requesting this.

Let s just say "yes" now, -- So never never never take

the first "no" on a new concept -- It s terribly important that we listen

to our youngsters -- Some very interesting things are happening in the Navy.

I know one case of a young Lieutenant junior grade who went aboard a ship -- Navy thought it was too small to have a computer -- He took his own computer aboard,

he was an admin -- Pretty soon he had all the ship s records in his computer, he was getting all the reports out on time; beautiful, accurate,

everything was just marvelous -- When he was transferred, the captain had to buy his computer.

I know another case where the commander of a squadron was told to take his squadron out to a carrier -- You found that when he did, he would have

to leave all his maintenance records in the naval air rework facilities in RF.

This didn t please him at all. He wanted to take and its records of his planes with him -- So we went out and bought

himself an Apple where the assistance of an ensign and a DP and the if he -- Borrowed, stole, liberated copying

his records from the North into is -- Apple, got a case for it, put it in the

space behind his seat, which is supposed to take his suitcase, and flew off to the carrier with all

of his maintenance records and a computer with which to keep them up to date. Every commander

of every squadron should have that. Somebody said, um, are you supposed to do that? He said,

I didn t ask. I long ago discovered -- of course, you don t all have the same advantage

I have -- but I long ago discovered that the best way to get something done was to do it --

And if necessary, apologize -- It s much easier to apologize. You have no idea, oh gee, I didnt,

"I couldn t do that" -- I can turn into the most helpless old female you ever saw. We ve got to listen to our youngsters,

we ve got to do the new things, and it isn t too hard to apologize. Believe me -- We had another case:

young electronic technician, first class, out in the Pacific fleet, build a computer.

The PR (manner?) we shipped thought this was terrific. So we took a picture of the sailor and his computer and put it in the Navy

Times. Admiral Collins saw it. So I wrote a letter to the sailor and congratulated him, and he sent it direct through the mail instead of sending it through channels.

So the sailor decided that the Admiral could write him direct, he could write the Admiral direct. And he did. And he thanked the Admiral for as he pointed out,

he didn t know Admirals read Navy times, but he was glad they did. [TIME: 00:30:03] He then went on for 10 pages,

both sides single spaced, and told the Admiral exactly what was wrong with the computers in the

Pacific fleet and what ought to be done about it. There s probably the best survey we d ever seen --

So the Admiral reached out his hand and said ET1 (?? problematic), Pacific fleet to Norfolk.

He gave them three more ETs and some DPs, that s our programmers, And some money, told them to build a computer. In four months time,

out of off-the-shelf components, they built it. Three small boxes, database management system

and everything, just beautiful. They set them up as the micro evaluation group. It s under the Naval Regional Data Center in Norfolk --

They ve run every micro on the country and run most of the software -- they know exactly what s available and what you can do with it -- Anybody in the Navy thinking of getting

micro-computers can consult with them and they ll give them real good, solid help. Writing the RFP or acquiring the computer that they need for that job.

Three, three-and-a-half, four months ago -- I ve forgotten just when -- they put on a seminar on micro-computers. They didn t think they d really get very many people,

they hoped for a hundred people and had to cut it -- had to cut it off when they got three hundred. They got a hall in one

of the local Norfolk buildings. They had booths. They leaned on all the micro manufacturers each to bring in their micro, and they had-

Everyone loves micros. I think there were 27 or something like that of them. Every one of those micros running an actual Navy problem. So when the Navy came in, they could

see the micros doing their kind of problem. They ve got some marvelous speakers.

Probably one of the most successful seminars on micros I ve ever seen, all put on by those young enlisted men. In fact, Slater, who s now chief, has

recently written an excellent paper: "Everything you ever wanted to know about microcomputers,

but didn t know who to ask". It s top notch. You can get a copy from -- from -- RDAC Norfolk. Excellent job, all the questions you should

ask when acquiring a micro, and why the different answers apply to different things.

It s top notch for an individual wants to get a micro computer. [TIME: 00:32:18] Or for a small installation, like our small naval bases and so on that want to get a microcomputer.

It s a beautiful job, contributed a tremendous amount to the Navy.

We ve got to learn to listen to those young men. They re bright as they can be, and they really know that equipment. And it s true of our young officers,

and our young enlisted men. We ve got to learn to listen to them. Because the upward most people have been much too busy managing things

to keep up with the technical developments. There s something else that was driving me

towards the future and worrying about the future. When I met Mark 1 back in 1944, Mark 1 was 51

feet long, 8 feet high, 8 feet deep. She was in a magnificent glass case,

designed by Norman Bel Geddes. and what s more, she had 72 whole words of storage -- each word consisted of 23 decimal digits

and an algebraic sign. And in addition, she could do three additions every single second --

Three times every second, she could get two quantities from memory, add em together, and put the answer back. That sounds pitiful to you today,

but if you go back and look at the newspapers and magazines of that period, you ll find that

Mark One was the most remarkable tool that man had ever built because she was the first tool

that assisted the power of his brain instead of the strength of his arm, the very first one.

She did an addition in 333 milliseconds, 3 additions per second, 333/1000ths of a second.

We didn t stop there. There were a lot more computers built during the rest of the war -- most of them under contract to the Department of

Defense at various universities. Not till 1951 did we have the first commercial electronic computer,

and that was the old Univac One. And a year ago goal at the National Computer Conference, they celebrated her 30th birthday. She even got a birthday cake.

And UNIVAC 1 could do an addition in 282 microseconds, 282 millionths of a second,

and we were going a thousand times faster. [TIME: 00:34:33] We didn t stop there. By 1964, out came the first

of the CDC 6400s, and it did an addition in 300 nanoseconds, 300 billionths of a second.

And we were again going a thousand times faster. Now, if you re a nut about the future, as I am,

naturally you have to try and write the next line -- see what it looks like. 19 question mark: will we need an XYZ system that adds in 300 pico-seconds, 300 trillionths of a second

for a complete addition? Storage to adder, storage to adder, add em together and put the answer back another thousand times faster? Answer is we need it right now for a couple of

problems, so what you needed very badly -- The population of the world is increasing.

That means we have to increase food supplies. The biggest assist we could give to increasing

food supplies would be better long term weather forecast. Yes, you may remember a couple of years back they planted corn out in Iowa --

Before it was fully rooted, heavy rains came wash it all out that had to wait for second shipment of seed and fertilizer plant

again was delayed the early frost got it -- If they d known the rains were coming,

they could have delayed the first planting and would have had that crop. Yeah, we do not today have a computer which will run a full-scale model of

the big heat (??problematic) engine which consists of the atmosphere and the oceans. We haven t even tested all of our models. Now that didn t matter til a few years ago; we didn

t have the data to feed into those models -- The Navy was dropping radio-equipped buoys in the rivers and the oceans to get more information; we were putting sensors on commercial airliners,

recorded on tape and took em off when they landed. But now we have the satellite photographs.

Those satellite photographs -- the landsat photographs -- are so darn good that when they re fully enhanced by computer, we can actually tell how high the waves are out in the middle of

the Pacific; we can tell what the temperature of the ocean is 20 feet below the surface. Of course,

there s a catch -- to fully enhance a satellite photograph takes 10 to the 15th power arithmetic operations -- that

s close to 3 days and our best computers and the weather s already happened. Yet we desperately need that information. There s another area in which we re

going to need computers. The news magazines -- it s one that every so often they turn it up.

I think the Corps of Engineers worries about it, but nobody seems to really point at it very hard.

That s the question of management of water -- My sister lives in northern New Jersey.

A year ago spring, they were limited to fifty gallons of water a piece, a day and they came around and looked at the water meters and

if anybody used more than that they fined them. Down in Norfolk, they began to run short of water.

Now, the city of Norfolk draws its water from wells, so they decided they had better drill

a couple more wells. And they got awful cute about it, they drilled them in the corner of the naval base and thought they d get away with it -- but they were in Suffolk county.

So you know, Suffolk county is suing Norfolk County for stealing their groundwater. Nobody s getting (the?) water,

of course. Down in Florida they use so much water they opened huge sinkholes and dumped houses and cars into them.

Out in Colorado, the eastern half of the State s dried, the Western half has money -- (I mean?) water -- So, um, same thing. So, um,

the Easterns think it d be a ducky idea idea to poke a tunnel through the Rockies, and get water from the western half. No way the Westerners gonna give

their water to the nasty old Easterners! In fact, Colorado, Nevada, California, all those states out in- out there are in the courts, fighting over who can draw how much groundwater

from where, and how much water from which river. Water supplies are going to be one of our major

problems of the future. We may even import water from Canada, instead of oil. Can you imagine what kind of computer

power it s going to take to manage water, so that every individual in the United States gets his fair share of pure water? [TIME: 00:38:44]

It s going to be one of the biggest jobs we ever tackle. At the other end of the scale, we need the itty bitty computers. I m awfully fond of a small town

in New Hampshire -- used to have sort of a septic system and a great, big, open, burning dump.

Along came the EPA and said you can t do those awful things anymore. We ll give you a large sum of money You will put in a (tertiary?) treatment

plant for the sewage and an incinerator in place of the dump, so they did. They even had a parade with a band and everything when they dedicated the

incinerator -- they love parades in New England. And then they found they had another problem.

Because they took the EPA money, the nice, little, old lady who keeps the town records,

which used to be two lists, one a list of the taxpayers, checked them off paid taxes, the other was a list of (?? problematic), she d check them off at town meetings.

But now she has to report to the township, the county, the state, the federal government, EPA, OSHA, EEOC, IRS, Social Security, government reports.

Every one of them is arranged differently and totaled differently. And she s going to have to have a computer just to get the government reports out.

And that s happening to every small business, every doctor, every lawyer, and every small town across the country. We re still going to need to the itty-bitty computers, everything from

the itty-bitty up to the great big ones. I said we re going to have some trouble getting there. To explain that

I have to explain something about myself. I m an extraordinarily annoying employee.

I normally drive all of my bosses totally nuts, because I won t do anything until I

understand what I ve been told to do. So when you tell me to do something, I start asking questions, until I get a clear picture of what I ve been told to do.

Well they told me that first computer was adding in milliseconds. So now I naturally said what s a millisecond? Well, they told me it s a thousandth of

a second, and I had a problem immediately. I could see a second go by on the clock, but darned if I could see a thousandth of it. So I said "please show me a millisecond".

And nobody, but nobody would show me a millisecond. Time went on with me still fussing, until somebody stuck a finger on one of my programs, and said:

"Hey you wasted 3 -- 5 microseconds.: [TIME: 00:40:59] And I said, "so what?". "What s a microsecond?" Well

they told me it was a millionth of a second. And again I had a problem. In the first place, I didn t know what a million of anything was. The biggest check I d ever seen was

less than a thousand dollars. I didn t know what a million was, and if I didn t know what a million was, I didn t know what a millionth was.

And I fussed and fumed. I wanted to know what a microsecond was. I got nowhere. Pretty soon, over in the engineering building, they started talking about

circuits that act on nanoseconds, billionths of a second. Well that really had me on the ropes,

because in the first place I didn t know what a billion was, and I don t think most of those guys up in Washington do either! And if you don t know what a billion is, how on Earth do you know

what a billionth is? I fussed and fumed. Finally, one morning, in total desperation, I called over

to the Engineering building and I said, "Please cut off a nanosecond and send it over to me."

And I ve brought you some today -- Now what I wanted when I asked for a nano second was- I wanted a piece of wire, which would represent the maximum distance that electricity

could travel in a billionth of a second. Because it wouldn t really be through wire, it would be

out in space at the velocity of light. [TIME: 00:42:11] So if you start the velocity of light and use your friendly computer, you discover

that a nano second is 11.8 inches long -- Maximum limiting distance that electricity

can travel in a billionth of the second -- Well, I was real happy with my nanosecond, I

looked at it from all angles- I thought about it. I looked at wall switches and counted the distance

some of those lights went on and I m like "gee these these may have taken a couple thousand of nanoseconds" -- Finally at the end of about a week,

I call back and said: look, I need something to compare this to. Could I please have a microsecond? microsecond? I ve only got one microsecond so

I can t give you each one. There s a microsecond. Nine hundred and eighty four feet. I sometimes

think we ought to hang on over every programmer s desk, so they ll know exactly what they re throwing away when they throw away a microsecond. I hope you all get some of these nanoseconds.

I ve got lots of them with me. They re absolutely marvelous for explaining to

wives and children and -- admirals and generals. [TIME: 00:43:14] And you may find yourself in a spot where you have to explain why two pieces of

equipment have to be close together -- Or explain to an Admiral why it takes so damn long to send a message by satellite because they re an awful lot of nanosec --

Very effective, they ll believe you. So you may need a nanosecond, and I hope that gets them -- I hope you ll feel free to use this demonstration

If you need it. There s only one thing you have to be careful about if you re going to use the demonstration. -- Normally, I put these in

my overnight bag and check it -- One day I put on my shoulder bag and went down to national airport -- And it took me twenty minutes to

explain nanoseconds and microseconds before I could board an airplane. -- So if you ve got them around with you be sure you check them. I ve

got lots of nanoseconds for you here -- I bet you didn t know and nanoseconds came different colors, but they do -- But I said I wanted to add in 300 picoseconds.

Now a picosecond is a thousandth of a nanosecond.

The best way to make picoseconds is get one of those big pepper grinders, and you can make picoseconds all over the table.

300 picoseconds is going to be a third of a nanosecond. And there s my problem. I haven t got enough distance to get from this- add this or add

the two together and put the answer back. I m beginning to push the velocity of light.

Now Dr. Einstein very carefully explained to us that when matter obtains the velocity of light, matter turns into energy. It goes poof -- And of course, I m perfectly willing to

admit that our bright, young engineers are going to get beyond the velocity of light -- They re going over into that anti-universe, where they have white holes and talk to all the Clarks

and left Johnson blue-ons and everybody else -- But not in the next five years, and I need

that computer before then. So what am I going to do -- Well I could use my common sense -- Except that seems to be the last thing we

ever use in connection with computers. Qualify won t use common sense.

Maybe I can use history. Back in 1976 we got well accustomed to looking at early history. Let s try that.

Now, back in the early days of this country, when they moved heavy objects around, they didn t have any Caterpillar tractors, they didn t have any big cranes.

They used oxen. And when they got a great big log on the ground, and one ox couldn t budge the darn

thing, they did not try to grow a bigger ox. They used two oxen.

And I think they re trying to tell us something. When we need greater computer power, the answer is not get a bigger computer -- it s get another computer.

Which, of course, is what common sense would have told us to begin with. Incidentally, common sense is a legitimate scientific technique.

The mathematician Polya, who worked at Princeton- he s the man who wrote the two volume text on techniques of problem solving- he also wrote a nice little anchor paperback, "How

to Solve It". And one entire chapter is devoted to the use of common sense and solving problems.

Yet we sometimes forget to use it. So the answer is that to get the computer part, we re going to need -- we re going to have to

build -- systems of computers. Of course, the first answer anybody ll give you to that is that ll cost too much, but it won t anymore. The cheapest, complete computer you can buy

today is probably the old Intel 80-21, the first of the 4-bit computers on a chip:

64 words of data storage, 1000 words of program storage -- those are down to 13 cents a piece if you buy a hundred of em -- There s nothing to stop us from building

systems of computers. Course I walked into one difficulty the minute I proposed the idea. I decided that if I was going to have systems of

computers, I d need three dimensional flow charts. So I got some plastic plates and I could draw

charts on each one, pile them up, looked like three dimensional chess. When I connected between the plates, I used little pieces

of string and Scotch tape, but they fell off. Finally I remember tinker toy and got a nice

tinker toy set and it had to square things and round things and sticks to put them together and I started building three-dimensional flow charts. [TIME: 00:47:30]

But I ran out of pieces -- So I wrote out a requisition for two large tinker toy sets -- Two days later, here s the boss:

"Well, Grace, what are we doing now?" -- I have a better suggestion for you today:

get some of those sets. the chemist used to show you molecules. Red balls can be computers, blue balls can be databases, yellow balls database managers, green balls

switches. And you can build a model of a system of computers and how they communicate and which ones

are connected to which others. And you re going to have to get out of the plain of the paper. You can't write, draw em on flat paper anymore. They ve got to be in three dimensions,

and you re going to have to explain to people what these systems of computers are doing, and I think the best solution is get one of those chemistry sets if you can. --

Of course you may have explain why you re ordering one but -- At least I warned you what happens when you ask for such things out of the thin air.

That concludes the first part of Future Possibilities: Data, Hardware, Software, and People, delivered to the NSA workforce in 1982 by then-Navy Captain Grace Hopper.

We'll bring the second half of the lecture on this feed next week.

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