FROM THE SUN TO THE STARS
Transcript including narration (in caps) and sync dialog (lower case.)

Existing “open” captions (lower thirds and web icons and language sub-titles noted.)

Underwriter announce:

“FROM THE SUN TO THE STARS” IS MADE POSSIBLE, IN PART, BY NASA, THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION.

(Sputnik beep)

Narration:

IN JUST FIFTY YEARS, WE’VE GONE FROM ONE SIMPLE SATELLITE CIRCLING EARTH…

…TO MANY THOUSANDS OF OBJECTS ORBITING OUR PLANET.

THE FIRST DISCOVERY OF THE SPACE AGE WAS THAT BELTS OF RADIATION SURROUND US.

NOW WE KNOW THAT FORCES ORIGINATING AT THE SUN EXTEND OUT ALMOST EIGHT BILLION MILES, TO THE VERY EDGE OF OUR SOLAR SYSTEM.

(Music swells)

…AND THAT OUR HIGH-TECH CIVILIZATION IS MIGHTILY IMPACTED BY “SPACE WEATHER”

NICKY FOX: (no lower third here)
We live in the atmosphere of the sun so when the Sun sneezes the Earth catches a cold.

IT WAS THE “INTERNATIONAL GEOPHYSICAL YEAR” OF 1957 THAT LAUNCHED THE SPACE AGE.

TWO THOUSAND SEVEN AND EIGHT HAVE BEEN WHAT’S KNOWN AS THE “INTERNATIONAL HELIOPHYSICAL YEAR” OR “IHY.”

IT’S A TIME TO PLAN NEW SPACECRAFT…

…AND TO RECRUIT A NEW GENERATION OF TEACHERS, STUDENTS, AND SCIENTISTS IN NATIONS ACROSS THE GLOBE TO WORK IN SPACE PHYSICS.

(Segment titles – text over black – fly in rapidly)

EACH ACT IN OUR PROGRAM STANDS ALONE… BUT TOGETHER THEY'RE A COMPREHENSIVE OVERVIEW OF IHY…

AND WHEN YOU SEE THIS ICON, THAT'S A SIGNAL THERE'S LOTS MORE INFORMATION ONLINE.

(Music change)

WE'VE COME TO UNDERSTAND THE SUN AND THE EARTH ARE CONNECTED…

…AND THAT THE FORCES WHICH SPREAD OUT FROM THE SUN TOWARDS THE STARS – THE NEW SCIENCE CALLED "HELIO-PHYSICS" – MAY HOLD SECRETS TO POWER OUR FUTURE.

Galaxy zoom back with text read-on: no need for captions

Heliophysics - the study of the system composed of the Sun's heliosphere and the objects that interact with it…

Closely tied to the study of "Space Weather" and the phenomena that affect it.

MAIN TITLES

FROM THE SUN TO THE STARS
The New Science of Heliophysics

(music)

Segment titles/chapter head:

Space Weather
& Global Society

Blowing in the SOLAR WIND

(wind)

BARROW, ALASKA… NORTHERNMOST TOWN IN THE UNITED STATES.

Radio announcer:
"Outside here in Barrow, a little warmer than Pluto. Clear, 28 below. Winds westerly. Wind chill, 48 below. The local news coming up."

JANUARY 23RD, 2008…

THIS WILL BE THE FIRST SUNRISE AFTER 65 DAYS OF DARKNESS

RESEARCHERS HAVE GATHERED HERE FOR A SPECIAL "INTERNATIONAL HELIOPHYSICAL YEAR" CONFERENCE TO EXPLORE SUN-EARTH CONNECTIONS AND POLAR SCIENCE.

EARL FINKLER (Radio announcer)
"Well, Jay, you're with NASA, I understand?"

L3 Jay…
JAY FRIEDLANDER
NASA Goddard Space Flight Center

JAY FRIEDLANDER
The scientists I work for are all studying the aurora and its effects on the Earth. And last night, we went out and saw some really incredible auroras. And to just come up here, see those lights in the sky, flashing out over the Arctic Ocean, that's why we were here. I mean that, like, just made it all worth it.

L3 Earl…
EARL FINKLER
KBRW radio, Barrow AK

FINKLER
"Now let's go to the *Earth* weather here… up in the Arctic."

(Compressed audio, as heard over radio, of NOAA weather forecaster☺

For today, becoming mostly clouds and flurries developing, highs near 15 below. NW winds, 10 miles per hour, becoming 15 in the afternoon…

APART FROM PLANETS AND MOONS, WE MAY THINK OF OUTER SPACE AS *EMPTY*…

BUT THOUGH THE FORCES ARE INVISIBLE TO UNAIDED HUMAN EYES, OUR SOLAR SYSTEM IS FULL OF ACTION.

OUR LOCAL STAR, THE SUN, IS A SEETHING MASS OF GASES – MOSTLY HYDROGEN AND HELIUM – FUSING COLOSSAL AMOUNTS OF MATTER TOGETHER EACH SECOND…

THAT PROCESS RELEASES VAST AMOUNTS OF ENERGY.

THE SUN'S OUTER ATMOSPHERE CONSTANTLY BLOWS OFF INTO SPACE,

THIS IS THE EVER-PRESENT “SOLAR WIND.”

(text super: CORONAL MASS EJECTIONS)

BUT SOMETIMES, EXTRA-VIOLENT ERUPTIONS ON THE SUN, TRIGGERED BY PROCESSES WE STILL DON’T FULLY UNDERSTAND, RELEASE GUST OF MATTER AND ENERGY KNOWN AS “CORONAL MASS EJECTIONS.”

THESE CARRY THE SUN’S MAGNETIC FORCE FIELD CLEAR ACROSS THE SOLAR SYSTEM.

JUST LIKE EARTH, SPACE HAS WIND AND WEATHER.

(Music change)

BARROW – DURING ITS LONG POLAR NIGHTS – IS A PERFECT PLACE AND TIME TO OBSERVE THE EFFECTS OF THOSE STORMS FROM THE SUN.

(Spacey sound effect)

AURORAS ARE THE MOST FAMILIAR AND VISIBLE SIGN OF WHAT’S COME TO BE CALLED “SPACE WEATHER.”

L3
NICOLA FOX
Applied Physics Lab, Johns Hopkins

NICKY FOX:
The term “space weather” is often used to describe how the Earth changes in response to the Sun. We actually have different reactions to what is happening on the Sun.

Text read-on:
Aurora Borealis (fade to Northern Lights)

THE AURORA BOREALIS, OR “NORTHERN LIGHTS”, ARE EVIDENCE OF THE SUN’S INTERACTION WITH EARTH’S MAGNETIC FIELD AND UPPER ATMOSPHERE…

SOMETHING WHICH CAN BE SEEN WITH THE NAKED EYE AS WELL AS SCIENTIFIC INSTRUMENTS.

(Car driving on snow)

JONATHAN NICHOLS
We’re looking for auroras… we’re trying to take photos of auroras. Which means I either have to hold the shutter down …in this very cold wind, which isn’t very ideal. Or I have to try and take a timed exposure… so I’m attempting to do that.

JONATHAN NICHOLS
So this is an example of the auroras that occur on the Earth. And it's a pretty spectacular example that occurred only last night up in Northern Alaska.

L3 Nichols:
JONATHAN NICHOLS
Radio and Space Plasma Physics, U. Leicester

The energy that drives these auroras and these processes ultimately comes from the Sun.

What happens is the Sun is very, very hot, and it radiates not only heat and light, but it also radiates something called the "solar wind", which is a stream of charged particles which flow from the Sun in all directions.

PLANET EARTH HAS A ROTATING LIQUID METAL CORE BURIED DEEP INSIDE.

THAT GENERATES A MAGNETIC FIELD, WITH LINES OF FORCE EMERGING CLOSE TO EARTH'S POLES.

Web icon
Suntostars.info/magnetosphere

THE FIELD LINES EXTEND OUT INTO SPACE CREATING WHAT'S KNOWN AS EARTH'S "MAGNETOSPHERE" – A TEAR-DROP SHAPED BUBBLE, LARGER ON THE NIGHT SIDE OF THE PLANET, OPPOSITE THE SUN.

THE SOLAR WIND BLOWS CHARGED PARTICLES FROM THE SUN INTO THE EARTH'S SPACE ENVIRONMENT.

L3 Kirsti:
KIRSTIE KAURISTI
Space Research Unit, Finnish Meteorological Inst.

KIRSTI KAURISTIE
And there they have some interactions with the magnetic field of Earth. And consequently they precipitate to the atmosphere and collide there with atmospheric particles, and in this reaction you get some light.

(Music changes)

THE SOLAR WIND CARRIES CHARGED PARTICLES ACROSS THE ENTIRE SOLAR SYSTEM.

OTHER PLANETS, LIKE JUPITER, ALSO HAVE AURORAS.

BUT BECAUSE THIS GAS GIANT IS MAINLY HYDROGEN AND HELIUM, THE AURORA'S COLORS ARE DIFFERENT FROM THOSE ON EARTH, WITH OUR NITROGEN / OXYGEN ATMOSPHERE.

AS SEEN BY THE HUBBLE SPACE TELESCOPE, SATURN HAS A CROWN OF AURORAS, ADDING TO THE BEAUTY OF ITS RINGS.

AURORAS ARE SPECTACULAR BUT THEY'RE ALSO A SIGN OF SUN-EARTH INTERACTIONS WITH IMPORTANT PRACTICAL CONSEQUENCES.

NICKY FOX:
These reactions in our own atmosphere have effects on life and society.

For example when you see very bright aurora, that is dumping huge amounts of high-energy particles into our atmosphere causing it to glow.

Those particles can have effects for astronauts that are in orbit.

JONATHON NICHOLS:
It can short out satellites and communications. And also massive currents can be induced in pipelines, and power lines across the northern latitudes.

TODAY WE ALSO RELY ON SATELLITES BRAVING SPACE STORMS TO MONITOR WEATHER DOWN HERE ON THE SURFACE OF THE PLANET.

NICHOLS:
So it's crucial that we really understand the causes of the auroras not just because they're pretty but because they really do affect life not only at the very northern latitudes, but people who use satellite TV or anything, all around the globe.

(Music change)

Text read-on:
Aurora australis dissolve the Latin into the English, Southern Lights)

AT THE OTHER END OF THE PLANET FROM BARROW, THERE ARE THE "AURORA AUSTRALIS", OR SOUTHERN LIGHTS.

IN ANTARCTICA RESEARCHERS IN REMOTE FIELD CAMPS RELY ON HIGH FREQUENCY RADIO FOR COMMUNICATIONS.

(Controller voice heard over radio)

FLIGHT CONTROLLERS HAVE TO CHECK WEATHER BEFORE PLANES CAN TAKE OFF.

JUST AS IN THE NORTH, COMMUNICATIONS CAN BE DISRUPTED BY SPACE STORMS.

L3
MARK MOLDWIN
Earth & Space Sciences, UCLA

MOLDWIN:
And here in Antarctica, all of our communication is through satellite dishes back up to satellites and then back to the United States, or wherever in the world you are trying to communicate. And so scientists like myself are studying space weather so we can predict when the Sun is being violent, and how we can protect our satellites.

(Sound effect and music transition)

IN AFRICA, CLOSE TO THE EQUATOR, YOU'LL LIKELY NEVER SEE AN AURORA.

BUT EVEN HERE, SPACE WEATHER HAS SIGNIFICANT IMPACTS.

L3 EY
ENDAWOKE YIZENGAW
Earth & Space Sciences, UCLA

ENDAWOKE YIZENGAW:
And if you go to Africa and ask about "space weather", they will consider you as… you are joking

(Please note that Endawoke continues with OPEN CAPTIONS to help understand the content: no CC need.)

because they need bread right now.

But space weather is a key issue for development.

It can knock out our communication and navigation system.

Without that you cannot develop.

So space weather is not a luxury science or whatever.

It's a basic science.

We have to understand what is going on.

We have to know the space weather impact in advance.

(End OPEN CAPTIONS)

(Music transition)

TO MAKE BETTER PREDICTIONS, RESEARCHERS WANT TO KNOW THE UNDERLYING PHYSICS OF SPACE WEATHER JUST AS WELL AS WE UNDERSTAND THE ANNUAL CYCLE OF SUN AND SEASONS.

L3 Cooper:
JOHN COOPER
Conference coordinator, NASA Goddard

JOHN COOPER
The Sun is… hasn't quite risen above the horizon yet. And it will do that tomorrow, on January 23rd, and so we should just see the Sun itself, poking above the horizon for about a half an hour or so, and that will be the first day of sunrise of this year, and this location.

L3 Brower
HARRY BROWER, Jr.
Dir., North Slope Borough wildlife management

HARRY BROWER, Jr.
First day the Sun come peaking over the horizon! (Chuckles.)

After being in the dark for at least 60 days, first peak over the horizon, and everyone go… starts standing out there and shouting joy – ya know – "The Sun is back! The Sun is back!"

(Web icon:
Suntostars.info/polargateways)

TROY CLINE (off camera, so no super)
How about everyone give a cheer for the Sun?

(Cheers and whoops)

(Singing)

"Here comes the Sun, dah-dah-dadah…"

(Laughter)

"Where's the champagne?"

IN 1957 A NEW SCIENTIFIC DAY WAS ABOUT TO DAWN, AS HUMANS TOOK THE UNPRECEDENTED STEP OF REACHING UP INTO SPACE – A PROCESS THAT WOULD ULTIMATELY SOLVE THE MYSTERY OF WHAT TRIGGERS THE AURORA.

(chapter head text super)

SCIENCE YEARS and
"EXPERIMENTS IN CONCERT"

Searching for causes of the AURORA
THEN and NOW

(Fast typewriter text effect – "THEMIS" "TIME HISTORY OF EVENTS AND MACROSCALE INTERACTIONS DURING SUBSTORMS")

IN FEBRUARY 2007 NASA LAUNCHED A SATELLITE CALLED "THEMIS" – WHICH STANDS FOR THE "TIME HISTORY OF EVENTS AND MACROSCALE INTERACTIONS DURING SUBSTORMS."

SUB-STORMS ARE THE EXPLOSIVE ONSET OF AURORAL ACTIVITY, AND THEIR CAUSE HAS BEEN A LONG-STANDING SCIENTIFIC MYSTERY.

ONCE IN ORBIT, FIVE SEPARATE SPACECRAFT WERE RELEASED AND TOOK UP STATION IN A CAREFULLY PLANNED FORMATION.

(Web icon
suntostars.info/themis)

DOWN BELOW, ALL ACROSS NORTH AMERICA, A NETWORK OF TWENTY GROUND STATIONS LOOKED UPWARDS.

NASA AND ITS PARTNERS IN CANADA KNEW THAT SOLVING THE MYSTERY OF *WHY*, *WHEN* AND *HOW* AURORAL SUB-STORMS ARE TRIGGERED WOULD TAKE SIMULTANEOUS OBSERVATIONS IN MANY DIFFERENT LOCATIONS.

THAT WAS AN EXPERIMENTAL DESIGN USED BACK IN 1881, DURING THE FIRST MAJOR SCIENCE YEAR.

Text super:
1st International Polar Year (IPY)
1881-1884

THE INTERNATIONAL POLAR YEAR OF 1881 TO 1884 COORDINATED SIMULTANEOUS OBSERVATIONS ALL AROUND THE ARCTIC.

L3
DALE CRUIKSHANK
Planetary astronomer, NASA Ames

Dale Cruikshank:
I think these big international efforts that are mounted to make International Polar Years and International Heliophysics Years are *extremely* valuable, and it's an enormous privilege to be any small part of these big international efforts which have traditionally yielded enormous new insight and information about the Earth and its relationship to the Sun, its place in the solar system, and all of the nature of Earth-Sun interactions in general.

IT'S NO ACCIDENT THIS IHY CONFERENCE WAS TAKING PLACE IN BARROW, ALASKA.

THIS WAS THE SITE OF SOME OF THE MOST SUCCESSFUL SCIENCE DONE DURING THAT FIRST "INTERNATIONAL POLAR YEAR."

Text super:
KARL WEYPRECHT
1838-1881

THE BIG IDEA OF IPY'S FOUNDING FATHER, KARL WEYPRECHT – AN AUSTRIAN EXPLORER AND NAVAL OFFICER – WAS TO DO "EXPERIMENTS IN CONCERT" – OBSERVATIONS OF THE POLAR REGIONS AT THE *SAME* TIME ON THE *SAME* DAY BUT FROM WIDELY DISPERSED LOCATIONS.

Text super:
Lt. Patrick Henry Ray, US Army
1842-1911

UNDER THE LEADERSHIP OF U.S. ARMY LIEUTENANT PATRICK HENRY RAY, THE AMERICANS SET UP CAMP IN BUILDINGS AT POINT BARROW.

LT. RAY MADE A POINT OF LEARNING SURVIVAL SKILLS FROM THE LOCAL ESKIMOS…

(webicon:
Suntostars.info/ipy1)

HIS MEN TOOK WEATHER OBSERVATIONS, DUG DOWN TO CHECK THE DEPTH OF THE PERMAFROST AND OBSERVED THE AURORA.

Text super:
International Geophysical Year
1957-1958

75 YEARS LATER, THE "IGY" OF 1957 CONTINUED THAT TRADITION, BUT WITH UPDATED INSTRUMENTATION.

A YOUNG JAPANESE RESEARCHER, SYUN-ICHI AKASOFU, CAME TO ALASKA TO

STUDY THE AURORA.

THAT BEGAN A DISTINGUISHED 50 YEAR PLUS CAREER THAT CULMINATED WITH THE FORMER GRAD STUDENT HAVING HIS NAME ON THE INSTITUTION HE HELPED FOUND.

AKASOFU:
I was very, very fortunate because what we call All-Sky Cameras which were operated at about 100 stations during the IGY

(webicon:
Suntostars.info/igy)

scattered all around the Arctic. All the datas were sent to the Geophysical Institute so I had full access

L3
SYUN-ICHI AKASOFU
Founding Director, Intl. Arctic Research Center

of All-Sky Camera datas from all over the world.

TILL THEN, CONVENTIONAL WISDOM WAS THAT AURORAS PROGRESS IN A STRAIGHTFORWARD WAY THROUGHOUT THE NIGHT, BECOMING FIRST MORE ACTIVE, THEN FADING.

USING THE ALL-SKY CAMERA DATA, GATHERED AT THE SAME TIME FROM WIDELY-DISPERSED LOCATIONS – – JUST AS WEYPRECHT HAD SUGGESTED ALMOST A HUNDRED YEARS EARLIER – YOUNG AKASOFU FOUND THE OLD IDEA WAS TOO SIMPLE.

(Text fading from one to the other in time with his comment:
QUIET/ACTIVE/PATCHY/QUIET/ACTIVE/PATCHY)

AKASOFU
The All-Sky Camera data showed that, showed clearly that, you see quiet phase, active phase, patchy phase and back to quiet, active, patches… sometimes three times a night.

NEAR-EARTH SPACE WAS WAY MORE DYNAMIC THAN ANYONE EXPECTED.

(Telecon audio)

THIS IGY RESEARCH WAS ONE FOCUS OF THE BARROW CONFERENCE, IN WHICH AKASOFU PARTICIPATED VIA TELECONFERENCE.

L3

JOHN COOPER
Conference Coordinator, NASA Goddard

JOHN COOPER:
Did you have a feeling at that time that this was really a historic event?

(Open captions)

AKASOFU
We felt that it was really great…

The greatest enterprise in geoscience history.

AKASOFU'S DISCOVERY OF THE SO-CALLED "AURORAL SUB-STORM" REMAINED CONTROVERSIAL UNTIL CONFIRMED BY SATELLITE OBSERVATIONS 10 YEARS LATER.

BUT THE EXACT CAUSES REMAINED UNKNOWN UNTIL NEW INSTRUMENTS WERE USED IN NEW WAYS.

AKASOFU
There's so much progress in the auroral science after the launch of satellites. Our study during the IGY is kind of "Stone Age" stuff… but nevertheless most of the things we found are still correct.

L3
KIRSTIE as before

KIRSTIE KAURISTIE:
If you look at the auroras you first see a stable arc – it can be stable for hours – and then suddenly it brightens up, and you start to see these fascinating curls, rayed structures, and everything. And the question is, what happens in the near-Earth space when this triggering happens?

IN THEIR FIRST YEAR OF OPERATION, THE *THEMIS* SATELITES OBSERVED A SUB-STORM BEGINNING IN SPACE, AT THE SAME TIME THAT THE GROUND-BASED OBSERVATORIES RECORDED INTENSE AURORAL BRIGHTENING AND STRONG ELECTRICAL CURRENTS FLOWING ACROSS NORTH AMERICA.

(Music change)

HIGH ABOVE SAN FRANCISCO BAY, MEMBERS OF THE THEMIS SCIENCE TEAM GATHER TO REVIEW PROGRESS.

Date/place super
THEMIS team meeting

Space Sciences Lab, UC Berkely
December 19, 2008

L3
CHARLES GOODRICH
Program scientist, NASA HQ

GOODRICH:
The sub-storm problem has been a great challenge for us for 20 years.

L3
DAVID SIBECK
THEMIS Project scientist, NASA Goddard

SIBECK
We've had many models in our field. It's boiled down to two competing models…

GOODRICH:
Was it a disruption of current near the Earth, or was it reconnection of magnetic fields and they release their energy farther down the tail.

(Text super Reconnection)

"RE-CONNECTION" IS A KEY CONCEPT IN SPACE PHYSICS.

DAVE SIBECK EXPLAINS HOW FIELD LINES ON THE NIGHT-SIDE OF EARTH'S MAGNETIC "TAIL" CAPTURE AND RELEASE ENERGY.

SIBECK:
It's stored up by stretching those night-side magnetic field lines like giant rubber bands, stretching them and stretching them as the energy piles up, and just like rubber bands, if you stretch them too far they snap, they snap and they release those particles, fling them back to Earth…

USING THEIR SMALL FLOTILLA OF 5 SPACECRAFT, THEMIS RESEARCHERS OBTAINED PRECISE TIMING OF EVENTS IN EARTH'S MAGNETIC TAIL JUST AS AN AURORAL SUB-STORM WAS BEGINNING.

SIBECK:
THEMIS has shown that it's magnetic reconnection, the process by which field lines come together, merge with each other, and release vast amounts of energy to the particles and plasma around them that drive these sub-storms.

IT WAS THIS SPACE AGE "EXPERIMENT IN CONCERT" THAT HELPED CRACK THE MYSTERY.

GOODRICH:
The great advance THEMIS has done is to spread out an array of spacecraft that can look in different regions simultaneously, and then quantify a great deal of the things that we were handling conceptually, and making assumptions about.

LATER IN 2008, THEMIS MADE ANOTHER DISCOVERY THAT COMPLETELY CHANGED OUR UNDERSTANDING OF HOW SOLAR WIND MATERIAL FLOWS INTO THE MAGNETOSPHERE. THAT'S IMPORTANT FOR UNDERSTANDING THE LARGE GEOMAGNETIC STORMS WHICH ARE RESPONSIBLE FOR THE MOST SEVERE SPACE WEATHER.

SIBECK:
THEMIS has been observing the entry of solar particles into the Earth's magnetic field.

L3
MARIT OIEROSET
THEMIS research, UC Berkeley

MARIT:
At the time of the observations, the THEMIS spacecraft were in the same orbit, following each other in the same orbit like pearls on a string, and that meant we could determine the exact thickness of that layer.

SIBECK:
And what we found is that this layer is far thicker than we had previously expected and that it's present under conditions very different than what we'd previously expected.

THIS IS "ROCKET SCIENCE" BUT – AS EVERY SCHOOL-CHILD KNOWS – THE NORTH POLE OF ONE MAGNET ATTRACTS THE SOUTH POLE OF ANOTHER MAGNET.

AND FOR 50 YEARS IT WAS ASSUMED THAT SPACE WEATHER WAS STORMIEST WHEN THE MAGNETIC FIELD IN THE SOLAR WIND AND EARTH'S OWN FIELD WERE OPPOSITE.

SIBECK:
We had previously thought that the particles enter during times when the Sun's magnetic field points southward, opposite the Earth's magnetic field.

But what we're finding here is that the particles are getting in for very different conditions.

MARIT:
Actually there is 20 times more particles entering when the fields are aligned than when they are not aligned.

THEMIS RESEARCHERS EXPLAIN IT LIKE THIS.

WHEN THE INTER-PLANETARY MAGNETIC FIELD ARRIVING FROM THE SUN POINTS *NORTH*, IT'S LIKE TURNING ON A STOVE AND LEAVING THE GAS OPEN.

LOTS AND LOTS OF PARTICLES GET IN TO CHARGE UP THE SYSTEM.

THEN WHEN A SOUTHWARD STORM ARRIVES, IT'S LIKE LIGHTING THE MATCH.

(Match ignites, explosion sound effct)

SO THE BIGGEST STORMS ARE LIKELY TO FOLLOW A "ONE-TWO PUNCH" INVOLVING BOTH NORTHWARD AND SOUTHWARD POINTING MAGNETIC FIELDS.

L3
JOACHIM (Jimmy) RAEDER
THEMIS researcher, Univ. of New Hampshire

RAEDER:
That is something that you wouldn't find in a textbook right now, and so, so we are in fact really re-writing the textbooks on quite a few aspects of space physics.

THE THEMIS SATELLITES AND THE GROUND STATIONS ARE AN EXPERIMENTAL DESIGN WITH ROOTS BACK IN THE FIRST INTERNATIONAL SCIENCE YEAR.

SIBECK:
THEMIS is a great example of experiments in concert. This mission wouldn't have been possible without the coordinated use of five spacecraft and a dedicated array of ground observatories, and that was a first for NASA.

Web icon
suntostars.info/greatobservatory

NOW NASA AND INTERNATIONAL PARTNERS HAVE SPACECRAFT DEPLOYED ACROSS THE HELIOSPHERE, CREATING A KIND OF "GREAT OBSERVATORY" STUDYING SUN-SOLAR SYSTEM INTERACTIONS.

L3
VASSILIS ANGELOPOLOS
THEMIS Principal Investigator, UCLA

VASSILIS:
The Sun-Earth connections research enters a new period in which in order to make progress we need multiple satellites, at multiple locations, fleets of satellites if you will.

And this is the era in which the atmospheric sciences, and weather… meteorology was, about a hundred years ago.

RAEDER:
I mean if you have only have one weather station you cannot actually see a weather front. But if you have actually a whole number of stations then we can see,see the picture, I mean we can already see where things are moving, where they come from. And we can make connections between things that we see at one point to things we see at another point, and understand what is the physics that links them.

THE BREAKTHROUGH DISCOVERIES OF 2008 WERE A FITTING 50TH ANNIVERSARY OF THE BIRTH OF THE SPACE AGE, AND PROOF ONCE MORE THAT WHEN YOU GET NEW DATA FROM NEW PLACES THERE WILL ALWAYS BE NEW DISCOVERIES.

Chapter head text:
From Explorer 1
to the Voyagers

The first 50 years of the
SPACE AGE

AFTER WORLD WAR TWO, BOTH THE UNITED STATES AND THE SOVIET UNION EXPERIMENTED WITH ROCKETS CAPTURED FROM THE GERMANS, THINKING OF THEM AS FUTURE WEAPONS.

Text super
JAMES VAN ALLEN
1924-2006

BUT BEGINNING IN 1951 A GROUP OF SCIENTISTS, INCLUDING JAMES VAN ALLEN AND SYDNEY CHAPMAN – HEAD OF THE SPECIAL COMMITTEE FOR THE IGY – THOUGHT OF ROCKETS AS *RESEARCH* TOOLS.

L3
STAMATIOS (Tom) KRIMIGIS
Johns Hopkins APL/
Worked with Van Allen

Tom Krimigis:
The technology was there. The unique situation with the Cold War was there, so that the rockets existed, to really launch satellites into space.

THEY DEVELOPED PLANS TO INCLUDE SCIENTIFIC SATELLITES IN THE UPCOMING INTERNATIONAL GEOPHYSICAL YEAR OF 1957-58…

…WHICH WAS ANTICIPATED WITH GREAT ENTHUSIASM, ESPECIALLY UP IN ALASKA!

BUT WHEN 1957 CAME, EXCITEMENT WAS ECLIPSED BY A SURPRISE FROM THE SOVIETS.

(Webicon:
Suntostars.info/sputnik)

Radio announcer:
"Today a new moon is in the sky, a 23 inch metal sphere placed in orbit by a Russian rocket."

PRESIDENT EISENHOWER PUSHED THE NAVY'S *VANGUARD* ROCKET PROGRAM TO CATCH UP…

BUT WITH EMBARRASSING CRASHES ON THE LAUNCH PAD, IKE GAVE THE ARMY 90 DAYS TO LAUNCH A SATELLITE.

VAN ALLEN WAS READY WITH A SCIENTIFIC PAYLOAD.

Newsreel audio:
"Time – late evening, Friday January 31st 1958. In a blockhouse at Canaveral. The countdown to Explorer 1…"

"5-4-3-2-1… my command…"

(launch sounds)

A SUCCESSFUL LAUNCH…

…AND AFTER 100 MINUTES OF SUSPENSE…

…CONFIRMATION THAT *EXPLORER 1* WAS IN ORBIT.

date/place super
January 31, 1958
National Academy of Sciences
Washington, DC

Radio announcer
"In plain language the United States was in the space business along with the Russians, and Explorer 1 was the beginning…"

(Webicon/explorer1)

KRIMIGIS (voice over)
The findings of Explorer 1 were a total surprise. They were totally baffled by way the data behaved.

THE FIRST EXPLORER SATELLITES SENT DOWN DATA ONLY WHEN OVER A GROUND STATION.

BUT *EXPLORER 3* HAD A SOLID STATE RECORDER.

NOW DATA FROM ENTIRE ORBITS COULD BE RETRIEVED.

TOM:
And then they realized that what was happening was that the intensity of the radiation was thousands of times greater than what they expected on the basis of ground measurements.

AMAZINGLY "EXPLORER" DETECTED RADIATION SO STRONG IT SWAMPED THE SENSOR COMPLETELY.

VAN ALLEN'S TEAM HAD MADE THE FIRST SCIENTIFIC DISCOVERY OF THE SPACE AGE.

IT WAS AN EXCITING TIME FOR SMART YOUNG GRAD STUDENTS LIKE STAMATIOS KRIMIGIS TO WORK AT IOWA WITH VAN ALLEN.

TOM
It was really hard to sleep at night. I mean, I can remember the sense of excitement and anticipation. And the terrific interest in getting into the laboratory, working on a sensor, working on what was going to be on the next spacecraft. Looking at the data that were coming back from one of the spacecraft, and saying, "What is this?" Every step was a discovery.

IN THE DECADES WHICH FOLLOWED THE U.S. SENT SPACECRAFT TO EVERY WORLD OF THE SOLAR SYSTEM.

(Whoosh)

New *Messenger*, Mercury stills and small movies:

FLYING BY THE INNERMOST PLANET, MERCURY, IN 2008 WITH *MESSENGER*…

AND SENDING THE *NEW HORIZONS* MISSION TO DISTANT PLUTO, DUE TO ARRIVE IN 2015.

PERHAPS THE MOST AMBITIOUS JOURNEYS WERE THOSE MADE BY THE TWIN *VOYAGER* SPACECRAFT…

PASSING JUPITER AND ITS COLORFUL MOONS…

FLYING BY SATURN… AND SEEING ITS RINGS IN CLOSE-UP

THEN LEAVING URANUS BEHIND…

AND PASSING THE BLUE CLOUDS OF NEPTUNE…

TOM:
The Voyagers were designed as planetary missions but those of us who were involved in designing the instruments made absolutely sure that the design of the spacecraft was not limited by consumables such as having enough power, and enough fuel to point the spacecraft or to move the spacecraft. So in the back of our minds we knew that it was going to be a long-term mission if the spacecraft worked well enough and lived long enough.

NOW, 50 YEARS AFTER THE BIRTH OF THE SPACE AGE, BOTH VOYAGERS HAVE PASSED THE TERMINATION SHOCK AND REACHED THE "HELIOPAUSE", THE REGION WHERE THE SOLAR WIND ENCOUNTERS INTERSTELLAR SPACE.

TOM
The solar atmosphere essentially explodes into space, and moves at a million miles an hour, the so-called solar wind. And the question from, actually from the beginning of the Space Era was, well, "How far does this go? Where does it stop?"

AS THE *VOYAGERS* NAVIGATED THESE UNCHARTED WATERS THEY ENCOUNTERED ASTROPHYSICAL PHENOMENA NEVER SEEN BEFORE.

TOM:
This hot gas which is about 100,000 degrees Centigrade slams into a boundary and begins to disperse.

AT THE DAWN OF THE TWENTY FIRST CENTURY, THE *VOYAGERS* FINALLY REACHED THE VERY EDGE OF THE HELIOSPHERE, AND LITERALLY PASSED FROM THE REALM OF THE SUN… OUT TO THE STARS.

TOM:
Our understanding has been expanded. We never expected to see the influence of the Sun and of solar flares out to these distances, and they seem to be there. We measure that with *Voyager*.

FROM 1958 AND THE DISCOVERY OF THE VAN ALLEN RADIATION BELTS UNTIL TODAY, ONE THING'S BEEN CONSTANT.

WHEREVER WE LOOKED WITH NEW SPACECRAFT AND INSTRUMENTS WE WERE SURPRISED.

L3 her

NICKY FOX:

It was really thought that these radiation belts were completely stable, they were just there, they didn't change. Nothing really happened with them. We now know just how variable those radiation belts are.

When we see big events coming from the Sun, they actually pump up, they get bigger, both in size and location, but also in the energy of the particles that are in those radiation belts.

BUT AS YET WE DON'T UNDERSTAND JUST WHAT DIFFERENCES IN THE SOLAR WIND MAKE WHAT DIFFERENCES TO NEAR-EARTH SPACE.

NICKY:
We see big events coming from the Sun, we see large aurora forming. But on other occasions we see large events coming from the Sun and they don't always have the same effect

WITHOUT KNOWING THE UNDERLYING PHYSICS, THERE'S NO WAY YOU CAN PREDICT WHAT'S NEXT.

DISCOVERING WHY THE RADIATION BELTS BEHAVE AS THEY DO MAY WELL MEAN KNOWING MORE ABOUT THE SOURCE OF WHAT'S CHANGING THEM… THE SUN.

TO SAFEGUARD THE ONGOING EXPLORATION OF THE SOLAR SYSTEM, BY HUMANS OR ROBOTIC SPACECRAFT, RESEARCHERS ARE WORKING ON NEW MISSIONS GOING PLACES NEVER VISITED BEFORE.

L3 (changed from before)
STAMATIOS (Tom) KRIMIGIS
Co-Investigator, NASA's Solar Probe Plus

TOM:
Where the fire is, at the Sun, we have relatively little knowledge… all we have is pictures and observations from a distance, but we have never *been* there, to see what the actual situation is.

And so what do we want to do? Well, we want to go to the Sun. You say OK, that's a pretty tough assignment. It is.

CAPTURING CLOSE UP KNOWLEDGE OF THE SUN MEANS SURVIVING EXTREME HEAT, AND INSTRUMENT-WRECKING RADIATION.

THAT'S WHAT NASA'S NEW *SOLAR PROBE PLUS* IS DESIGNED TO DO.

(webicon:
Suntostars.info/solarprobe)

KRIMIGIS

One has to get to a place where the intensity of the Sun, the solar radiation, is at least 500 times as much as it is at Earth.

CLOSE TO THE SUN, RUGGEDIZED SOLAR PANELS EXTEND, TO POWER THE MISSION.

KRIMIGIS
And we'll get to a distance of about, between 6 and 7 million kms from the Sun, and we are going to study the process that we know nothing about, and that is the heating of the solar wind.

L3
ROGER SMITH
Dir., Geophysical Institute, UAF

ROGER
A lot of what happens on the Sun happens seemingly without any organization behind it, so that we can really understand it well. We know some statistics about what happens on the Sun but do we know what's going to happen in the next second or two? Well, we can only guess at it because there can be things that things we don't understand.

EXPLORING THE SUN AND EARTH'S RADIATION BELTS ARE CUTTING-EDGE SCIENCE.

BUT "IHY" IS ALSO USING "SPACE WEATHER" TO EXCITE PEOPLE AROUND THE WORLD ABOUT THE BASICS OF SPACE SCIENCE, HOPING TO FIND THE VAN ALLEN'S AND KRIMIGIS'S OF THE FUTURE IN NEW PLACES..

L3 (this is different from before)
ROGER SMITH
US country coordinator, IHY

ROGER SMITH
Through a collaboration with the United Nations, the International Heliophysical Year has some outreach into nations where science is in need of some help. And that is… it's not that people cannot study science there, it's that they don't have the tools to help them do it.

Their countries are not well set up for that, and we have actually addressed this first in Africa.

(Chapter head text)
OPENING EYES
to
SUN-EARTH CONNECTIONS

IHY goes GLOBAL

ADDIS ABABA, CAPITAL OF ETHIOPIA, NORTHEAST AFRICA.

Teacher (off camera)
We are opening our eyes to science and technology, especially to the western world.

Since in America there is a technological advancement, they know many things, but in our case, since they get things mainly from books, since we do not have well-equipped laboratories, our students may not have sufficient knowledge as it is in the case of America.

L3
BEREKET DINA
Student, Menelik II Secondary School

BEREKET DINA (Student)
Science is very important to our country. To develop and to help my country, that's why I select to study science. That's why I need to learn physics, chemistry, biology.

Teacher: (off camera)
This is the right time for us to open our eyes so that we can go, learn with other populations of the world.

(Music and street sounds)

ETHIOPIA'S POPULATION IS NEARLY 80 MILLION, OF WHICH ABOUT 43% ARE UNDER AGE 15.

16 PER CENT OF FEMALE STUDENTS ATTEND SECONDARY SCHOOL.

FOR BOYS IT'S 28 PER CENT.

AS PART OF THE "INTERNATIONAL HELIOPHYSICAL YEAR" SPACE SCIENTISTS LIKE MARK MOLDWIN FROM UCLA AND DEBORAH SCHERRER FROM STANFORD GATHERED IN ADDIS ABABA.

SUPPORTED BY NASA, NSF AND THE UNITED NATIONS, THE AMERICAN RESEARCHERS LED A WORKSHOP FOR 70 ETHIOPIAN HIGH SCHOOL SCIENCE TEACHERS

(Music changes)

MARK MOLDWIN (starts VO)
Ethiopia has sort of a tourist logo as "the land of 13 months of sunshine." It's just a perfect setting to learn about the Sun, and the dynamic Sun, here in Ethiopia.

And looking and talking with these high school teachers, and how excited they are about the field, I am hoping they can convey that to their students. And so I would love to have space weather as a vehicle exciting students learning more about the world around them

L3
DEBORAH SCHERRER
Education Director, Stanford Solar Center

DEBORAH SCHERRER.
I was, whatever, 5th grade or something… and I remember reading in my "Weekly Reader" about the IGY. And so it had a major impact on me: that was the year I became really interested in astronomy. And so when I heard about the IHY, I said, that's cool. That's the 50th anniversary of the IGY, that's important to me, and it was important to me when I was in 5th grade, so it ought to be important to the kids now too. And it ought to be able to inspire them, just like it inspired me.

L3
NEGATU WOLDE YOHANNES
Physics teacher, Menelik II Secondary School

NEGATU WOLDE YOHANNES
Conducting such a meeting for high school teachers is very important because it is motivating us and we can also motivate our students.

(Music change)

EACH TEACHER RECEIVES 40 CARDBOARD SPECTROSCOPES & DIFFRACTION GRATINGS SO THEY CAN EXPERIENCE THE HANDS-ON ACTIVITIES THEY'LL LATER SHARE WITH STUDENTS.

SCHERRER (addressing the workshop teachers)
"So you will get a rainbow of colors, just like you do here. Plus these four strong lines. You see a scale, and lights and colors. You should just see a rainbow."

Text super:
SOHO (ESA/NASA)
SOlar and Heliophysic Observatory

THE SIMPLE SPECTROSCOPES SIMULATE HOW SPACECRAFT LIKE "SOHO" – THE SOLAR AND HELIOPHYSIC OBSERVATORY – USE DIFFERENT FILTERS TO DETECT DIFFERENT ELEMENTS ON THE SUN.

SCHERRER:
"What you're going to find out with these instruments is not only does it produce a rainbow of colors, but each element has a set of colors associated with that element."

MOLDWIN (to the workshop teachers)
“And so that’s how we can tell what the Sun is made out of. We look at the spectrum of light and we say, Oh, it has to be hydrogen, because I see the hydrogen. Each element is unique.”

SCHERRER (to the workshop teachers)
“This is the SOHO spacecraft. It’s the great solar observatory: it’s circling the Sun. And it’s a spectroscope. Almost everything on SOHO is a spectroscope! It’s just that theirs costs millions of dollars more. But it’s the same thing. It’s the same technology.”

OPEN CAPTIONS

Teacher (with sub-titles)
Because we are not well developed for science
So we have to improve our knowledge for physics and science.
If they get and like these instruments and devices
They will become scientists.
And they need more help from developed countries.

End captions

L3 Moldwin:
MARK MOLDWIN
Earth & Space Sciences, UCLA

MOLDWIN:
The great thing about space science is that it’s connected to what we want educated students around the world to know. We would like them to know physics, and chemistry, and biology, and literature, and the history of science. And by talking to teachers we have that multiplying effect.

So here in Ethiopia they have 60 students, and each teacher has four classes.

So each teacher has 240 students, so you multiply that by 70, and you can see that the type of impact of a one day workshop. Just by raising the awareness among the next generation of Ethiopian, not only scientists, but lawyers and politicians and businessmen and community leaders.

(Pan to sign: “I seek the Truth of Life through Education.”)

If they understand what science is and why we’re doing science, I think that will help everyone in the long run.

ONE OF THE WORKSHOP LEADERS IS ENDAWOKE YIZENGAW, BORN IN ETHIOPIA, BUT NOW A RESEARCHER AT UCLA

MOLDWIN (to the workshop)

“Endawoke Yizengaw, he’s Ethiopian, and he’s now one of the world’s greatest space physicists. And he’s working with me at UCLA.”

ENDAWOKE YIZENGAW
As a kid, I was tracking the cattle, keeping my cattles. (sic)

I was born from a farmer, a peasant family. My family is still a peasant. Which is 300 kms away.

As a scientist now, I am tracking the satellites!

(Music change)

MOLDWIN:
59% of scientists said they knew they wanted to be a scientist since they were a kid.

(Webicon:
Suntostars.info/ihyafrica)

SCHERRER:
To get them to understand how science works, how technology works, it’s a new way to think. This can open a new world…

L3
BERHANU GIRMA
High school teacher, Addis Ababa

BERHANU (teacher, with sub-titles)
Maybe you will have more scientists in the future.
We try to give them

OPEN CAPTIONS

some ideas that encourage them to
come to this science, I think.
That’s the best part of this workshop.

MOLDWIN (to the teachers)
“So this is an example of the certificate. And it’s sponsored by the United Nations, IHY and NASA. And it says that ‘This is to certify that…’ and you can write your name, ‘has participated in a space weather science and education workshop sponsored by NASA, the National Science Foundation as part of the IHY’ and it has the date.”

L3
DESLEGN KEBED
High school teacher, Addis Ababa

DESLEGN KEBED (participating teacher)
Astrophysics is an interesting part of physics

OPEN CAPTIONS

It's new for our country.
Especially for all Africans
This might introduce them to
this part of physics.

ENDAWOKE (to the teachers)
"Thank you very much, and thank you!"

(Applause)

(Music)

Chapter head:
Plugging the Gaps

New MAGNETOMETERS
and new RESEARCHERS

AS A RESEARCHER, ENDAWOKE YIZENGAW IS COMMITTED TO UNDERSTANDING WHY THE AFRICAN CONTINENT SEEMS TO BE HOME TO VERY UNUSUAL CONDITIONS, HIGH UP IN THE IONOSPHERE, THE LAYER OF EARTH'S ATMOSPHERE THROUGH WHICH SATELLITE SIGNALS PASS.

L3 Endawoke:

ENDAWOKE:
When you ask the question, why you are interested to Africa? Well, because what we can see here from the satellites - very big density fluctuation, we call it "scintillation", in that region, compared to the Pacific and the Australian sector.

(Word SCINTILLATION appears)

"SCINTILLATION" – SEEN HERE OVER THE UNITED STATES - MEANS FLUCTUATION IN THE NUMBER AND ENERGY OF IONOSPHERIC ELECTRONS…

RED INDICATES HIGH LEVELS, AND THAT CAN MEAN COMMUNICATIONS DISRUPTIONS.

ENDAWOKE'S DATA SHOWS THAT AFRICA HAS MORE OF THIS FLUCTUATION – ACROSS THE ENTIRE YEAR – THAN ANYWHERE ELSE ON EARTH.

(Zooming out sound effects)

ONE WAY TO STUDY EARTH'S UPPER ATMOSPHERE CAN BE SEEN ON THE WEST COAST OF GREENLAND, CLOSER TO EARTH'S NORTH MAGNETIC POLE.

HERE THE U.S. NATIONAL SCIENCE FOUNDATION SUPPORTS THE OPERATION OF A GIANT RADAR FACILITY.

POWERFUL GENERATORS CREATE A 120,000 WATT BEAM WHICH CAN STUDY PERTURBATIONS IN THE IONOSPHERE.

L3 Bob C
C. ROBERT CLAUER
Natl. Inst. of Aerospace, Virginia Tech

CLAUER:
Incoherent scatter radar is a very powerful instrument that allows you to make detailed measurements of the plasma and electro-dynamic phenomena on the ionosphere over a fairly large region.

CLAUER VO:
The other thing about Greenland is that it's well populated by other instruments and the West Coast in particular has a very dense chain of magnetometers.

A MAGNETOMETER IS ESSENTIALLY A FANCY FORM OF COMPASS, WHICH SHOWS HOW EARTH'S MAGNETIC FIELD IS CHANGING OVER TIME.

CLAUER:
Using magnetometers …optical observations of aurora …and the measurements from the radar

On camera
…really enable you to get a very good understanding of the electrodynamics of this region.

THE SONDRESTROM RADAR IS A COMPLEX AND EXPENSIVE FACILITY.

BUT SIMPLER AND LESS COSTLY MAGNETOMETERS CAN ALSO TRACK IONOSPHERIC DISTURBANCES.

MOLDWIN AND COLLABORATORS RUN A CHAIN OF MAGNETOMETERS THAT STRETCHES DOWN THROUGH SOUTH AMERICA, ALL THE WAY TO ANTARCTICA.

L3
MARK MOLDWIN
Earth & Space Sciences, UCLA

MOLDWIN:
We're down in Antarctica to deploy a magnetometer. And UCLA has just under 70 magnetometers around the world. We are deploying magnetometers in South America, North America, and here in Antarctica.

L3
DAVID GALVAN
Post-doc student, UCLA

GALVAN:
And so having these instruments spread out throughout the Earth is a great way to, kind of, study the near-Earth space environment from the ground and to get a really good comprehensive view of that.

MOLDWIN:
And so we have these magnetometers around the world, and they're essentially measuring all of these currents flowing in the atmosphere.

And so here in Antarctica, where the magnetic field of the Earth is coming down into the Pole, we have an array of magnetometers, and we have colleagues from the University of New Hampshire and the University of Maryland, and other universities that have a number of these instruments here, and we can sense what's going on in space, and so we can sense "space" weather from the ground.

THOUGH IN ANTARCTICA TO STUDY "*SPACE* WEATHER", *EARTH* WEATHER DISRUPTS THEIR PLANS.

FLIGHTS ARE DELAYED AND MOLDWIN HAS TO RETURN TO THE U.S. LEAVING POST-DOC DAVID GALVAN IN CHARGE OF REPAIRS.

TO FIX THE DAMAGED MAGNETOMETER, DAVID HEADS OFF TO A REMOTE DRILLING SITE IN WEST ANTARCTICA.

WITH THE WEATHER FINALLY CLEAR, HE TRAVELED THE 5 KILOMETERS TO THE MAGNETOMETER SITE.

…DUG UP THE INSTRUMENT.

…REPLACED THE BROKEN PARTS…

AND SOON GOT THE MAGNETOMETER WORKING AGAIN. THE NETWORK OF INSTRUMENTS WAS BACK IN BUSINESS.

GALVAN:
So it's been very interesting to kind of see how the places on the ground ready do correspond to places out in space. You're actually looking at, y'know, changes in the Earth's magnetic field

and that's kind of cool when you kind of think about it and how it's connected across hundreds of thousands of miles in space.

BUT WHILE MAGNETOMETER NETWORKS STRETCH FROM ALASKA TO ANTARCTICA, THERE'S A GAP IN COVERAGE SOUTH OF EUROPE, OVER AFRICA.

ENDAWOKE:
What you can see is the European and South African and the Antarctic, they got really good coverage. But in the African sector we didn't have that much coverage at all.

(Chart with graphics)

AS PART OF IHY, ENDAWOKE GOT HELP FROM NASA TO CLOSE THAT GAP.

(Webicon:
Suntostars.info/amber)

We proposed and get funded through IHY and NASA program to deploy four magnetometers in four different African countries.

That's really a good opportunity not only for me for assisting the developing nation, trying to do more research in that field.

WHILE ENDAWOKE AND HIS COLLEAGUES ARE WORKING TO GET NEW HARDWARE IN PLACE TO CREATE A CONTINUOUS GLOBAL NETWORK, STUDENTS AND PROFESSORS AT STANFORD UNIVERSITY ARE FOCUSING ON DEVELOPING THE HUMAN INFRASTRUCTURE.

THEY'RE DISTRIBUTING SIMPLE, LOW-COST INSTRUMENTS TO HELP RECRUIT NEW SPACE PHYSICS RESEARCHERS AROUND THE WORLD.

SHEILA (VO)
The way the program is set up, this system can be remotely deployed. So we usually send them out by mail…

L3
SHEILA BIJOOR
Electrical engineering and International relations, Stanford

SHEILA on camera:
…and Morris and I help the site hosts set them up remotely.

MORRIS to camera:
It's not just dropping these boxes and walking away. But we had a sense that we could really start some nice collaborations, and we could get some smart people behind the project, as well, working with us on these scientific questions.

Text super:
“AWESOME”
Atmospheric Weather Electromagnetic System for Observation, Modeling and Education

EACH DETECTOR COSTS ABOUT 2,000 DOLLARS AND IS CALLED “AWESOME” STANDING FOR… “ATMOSPHERIC WEATHER ELECTROMAGNETIC SYSTEM FOR OBSERVATION, MODELING AND EDUCATION.”

Morris: checking detector
Well, I think this one’s working. That’s good. (Laughs)

SHEILA:
The amazing thing about the AWESOME receiver is that it’s university level science instrument. So it’s a very high-tech science instrument. But it’s extremely low cost and it’s an easy to use and it’s portable.

(web icon
suntostars.info/awesome)

USING VERY LONG FREQUENCY, OR “VLF” DATA, NEW INVESTIGATORS AROUND THE WORLD ARE ABLE TO STUDY MANY DIFFERENT PHENOMENA.

MORRIS:
Anything that affects the upper atmosphere is fair game. Lightning affects the upper atmosphere. The Sun has a huge effect on the upper atmosphere. You have radiation belts…

SHEILA:
So maybe we can go downstairs and weigh it…

HIGH UP ON THE HILLS ABOVE STANFORD IS THE WILCOX SOLAR OBSERVATORY.

Text super read-on:
“SID”
Sudden Ionospheric Disturbance

DEBORAH SCHERRER, WHO’D HELPED RUN THE WORKSHOP IN ETHIOPIA, EXPLAINS THE SIMPLER “SUDDEN IONOSPHERIC DISTURBANCE” INSTRUMENT, OR “SID” MONITOR, DESIGNED FOR GRADE SCHOOL STUDENTS.

SCHERRER
It’s not much more than a simple radio receiver. In fact it is a radio receiver.

Scherrer L3 (repeat)

So we get data. It's very much like seismic data. Wiggle wiggle flare, wiggle wiggle flare.

Web icon
suntostars.info/SID

And it's very simple data for kids to read and understand.

SID AND AWESOME MONITORS ARE NOW WORKING IN HUNDREDS OF LOCATIONS WORLDWIDE.

SCHERRER:
The goal is to get the students excited about science and to excited about technology and learn how it works so that that they can be a literate citizen in the 21st century.

We have a lot of contact from the teachers who are using monitors in the schools. And they sent us some wonderful pictures of the students being involved either setting up the monitors.

And you can tell from the smile on their face how excited they are, about, you know this is mine, I built it, and it's collecting my data.

MORRIS:
We just get it started and then it just snowballs from there. You know, people will emerge as leaders in their own regions. People will think of their own problems and they'll just pursue them, and we just get them started and they will. They're writing papers. They're collaborating with each other.

SHEILA:
And what we hope is that we will form a scientific community of global researchers.

MORRIS:
Something very special can happen. They can sprout out of the ground. So I get a lot of positive satisfaction out of just watching that happen and knowing… just feeling like I had something to do with it, that's all.

THE ACTIVITIES OF THE UCLA AND STANFORD RESEARCHERS ARE TESTIMONY TO THE FACT THAT IN "IHY" THE "INTERNATIONAL" IS AS IMPORTANT AS THE "HELIOPHYSICAL."

L3 Nicky
Same as before

NICKY
IGY definitely led to the birth of Space Age and the whole space research phenomena. I think that the real impact of IHY has been to really broaden the community that is studying space science.

L3 Roger

ROGER
Political differences between countries don't come up when you're talking about science.

And so if we're going out as mankind, to investigate the heliosphere,

Chapter head text
LEGACY OF THE INTERNATIONAL HELIOPHYSICAL YEAR

Practical APPLICATIONS
and fundamental BREAKTHROUGHS

(Webicon
Suntostars.info/ibex)

IHY HAS SEEN THE LAUNCH OF NEW SATELLITES LIKE IBEX, THE "INTERSTELLAR BOUNDARY EXPLORER", WHICH USES COSMIC RAYS TO STUDY THE VERY EDGE OF OUR SOLAR SYSTEM.

RESULTS ARE JUST NOW BEGINNING TO EMERGE.

AND SPACECRAFT LIKE THEMIS CONTINUE TO MAKE EXCITING DISCOVERIES AS PART OF NASA'S HELIOSPHERIC "GREAT OBSERVATORY."

THESE ARE BREAKTHROUGHS IN FUNDAMENTAL SCIENCE, BUT THEY ALSO HAVE SOME VERY PRACTICAL APPLICATIONS.

L3 Sibeck as before

SIBECK
The aurora are just the visual manifestation of a dramatic range of processes that are occurring in Earth's magnetic field. Those processes can pump million amp currents into Earth's atmosphere and those currents can blow out transformers in power lines.

(Webicon
Suntostars.info/1989)

IN 1989 A SPACE STORM TRIGGERED A BLACKOUT THAT SPREAD RAPIDLY ACROSS CANADA.

RAEDER:
And that came at that time totally to a surprise of the operators of the power grid. They did not even know what hit them at that point.

SINCE THEN, WE'VE ALL BECOME MORE RELIANT ON CELL PHONES AND PAGERS.

IN 1998 ANOTHER SPACE STORM STRUCK.

(Webicon
Suntostars.info/1998)

RAEDER:
A few years back there was an outage that was space weather related of satellites that relay to pagers, and so all over the country we had pagers not working, I mean, which was very detrimental to society. I mean doctors, for example, use a lot of pagers, and if you can't get the doctor to the right place where you need them, at the right time, that's a very bad thing.

TODAY, OF COURSE, IT'S NOT JUST DOCTORS…

IN 1965, SATELLITE TV USING "EARLY BIRD" WAS A NOVELTY.

BY 2008, DURING THE BEIJING OLYMPICS, SATELLITES AND SPACE AGE COMMUNICATIONS CONNECTED THE ENTIRE PLANET TO A RAPIDLY CHANGING CHINA.

WORLDWIDE, A CUMULATIVE AUDIENCE OF 4.7 BILLION PEOPLE – 70% OF EARTH'S TOTAL POPULATION – WATCHED SOME PORTION OF THE BROADCASTS.

NOW MANY CELL PHONES CAN DOUBLE AS A GPS…

EY:
Google Maps, thanks to Google…

ADD TO THAT LIST OF BUSINESSES AND PEOPLE RELYING ON SPACE WEATHER, AIRLINES FLYING OVER THE POLES…

ASTRONAUTS ABOARD THE SPACE STATION…

SPACE TOURISTS WHO MAY SOMEDAY BOOK A TRIP ON "VIRGIN GALACTI"

(L3 as before)

MOLDWIN:
Just like you wouldn't want to fly through a hurricane, you would not want to be in space needlessly if there's a strong geomagnetic storm going on.

AND WITH TROOP MOVEMENTS AND ANTI-TERROR STRIKES RELYING ON THE ACCURACY OF GPS READINGS, “SPACE WEATHER” IS ALSO A MATTER OF NATIONAL SECURITY…

SIBECK (off camera)
We need to know when these disturbances are going to occur, and warn people.

RAEDER:
If we know that the outage is coming, we can take preventive measures.

SIBECK:
Just like we need to improve weather forecasting on Earth, we need to understand space weather.

BUT HELIOPHYSICS, AND EXPLORING EXOTIC ASTROPHYSICAL PHENOMENA, LIKE BLACK HOLES ORBITING EACH OTHER, MAY HAVE IMPORTANT IMPLICATIONS FOR FUTURE TECHNOLOGIES.

(L3 Tom)

TOM:
Basic science is always thought of as pure in one way or another but invariably it ends up finding an application in some everyday activity.

ROGER SMITH:
The processes that we are looking at in plasmas, in particular, are closely allied to those processes we are seeking to understand in order to generate power from nuclear fusion.

TOM:
If we understand the process by which the redistribution of energy happens at the interaction between the solar wind and interstellar space, there could be some practical applications of that.

THE SUN IS A GIANT BALL OF HYDROGEN GAS, A FUSION REACTOR SHAPED BY LINES OF MAGNETIC FORCE.

ON EARTH, WE NEED TO KNOW HOW TO CONTAIN FUSION REACTIONS.

UNDERSTANDING MAGNETISM ON THE SUN, AND THROUGHOUT THE HELIOSPHERE, MAY CONTAIN CLUES ABOUT HOW TO SOLVE THAT HUGE ENGINEERING CHALLENGE.

ROGER:
The time that we are able to use fossil fuels is coming to end, and the ability to do actually do nuclear fusion with hydrogen, it seems that that sort of power source would be almost endless.

(Webicon
suntostars.info/fusion)

ROGER:
Our distant environment between the Sun and the Earth is a very large plasma observatory, and that's how we get to the information that we need.

NO-ONE COULD HAVE PREDICTED TODAY'S WORLD WHEN THE SPACE AGE BEGAN IN 1957.

GALVAN:
Space physics is a fairly young field when you compare it to other branches of science. And the Space Age really only is only 50 years or so old.

And just to realize that many of the experts in the field were studying this in the IGY in 1957 and to kind of commemorate that 50 years later and realize that not many generations have passed between then and now.

IHY HAS BEEN ALL ABOUT NEW SCIENCE IN NEW PLACES…

BUT PERHAPS ITS MOST ENDURING LEGACY WILL BE THE NEW GENERATION OF RESEARCHERS WHOSE IDEAS WILL LAUNCH THE NEXT 50 YEARS OF SPACE EXPLORATION.

GALVAN:
It really kind of grounds you in that this is an exciting field, this is a new field, and even though there is so much that we understand now there is a vast majority that we don't, and that's all the more reason to study it even harder.

IN "ECCLESIASTES" IT'S WRITTEN …THERE'S NOTHING NEW UNDER THE SUN.

WE NOW KNOW THERE'S *ALWAYS* SOMETHING NEW *ON* THE SUN, AND OUT ACROSS THE HELIOSPHERE.

AND – IF WE KEEP LOOKING – NEW DISCOVERIES AWAIT US… OUT TO THE FARTHEST REACHES OF SPACE AND TIME.

(Music and end credits)

Underwriter announce:

"FROM THE SUN TO THE STARS" IS MADE POSSIBLE, IN PART, BY NASA, THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION…

end