# Five Fascinating Facts from a Half-Century of Landsat

*Pecora 2022 - October 25, 2022*

SLIDE ZERO

Good evening and welcome to:
**Five Fascinating Facts from a Half-Century of Landsat**

My name is Laura Rocchio…

SLIDE ONE

And this evening, we are going to **journey back** in time and **explore** some of **interesting stories** that we **uncovered**—or at least dusted off—**while conducting** our research for the book "Landsat's Enduring Legacy" A book which **chronicles the technical history** of the Landsat program.

*Journey – explore- research 4. Chronicles tech*

Part of that research involved **gathering technical documentation that was scattered** between different agencies and companies because of **Landsat's shifting management in the first half of its history**.

*Tech doc, id/interview vets, unwritten*

We also were able **to identify and interview over 50 "Landsat Veterans"** to help **capture the early unwritten history** of the program.

And, this book has **lots of tie-ins to the Pecora Conference**. It was **published in 2017 by ASPRS** via a NASA Space Act agreement and first **released at Pecora 20** in Sioux Falls that year.

The **authoring team includes two Pecoca Award winners**.

And **this year, in celebration of Landsat's 50th anniversary, NASA, USGS, and ASPRS** worked together to make the **digital version of the book open access**. So as of this summer, you can freely download the entire book, all **586 pages of it.**

*Pecora – 2017/20,*
*2 winners…*
*this year celebrate 50*

Now, on to the fascinating facts…

SLIDE TWO

**Finding Virginia Norwood** - #1

Who here has heard of Virginia Norwood, the woman dubbed the "Mother of Landsat"?

Ah, so Wonderful.

Earlier this month, Virginia was prominently mentioned in a special edition of USA Today… and leading up to Landsat 9's launch last year, she was featured in both MIT's tech magazine and Science Magazine. And after attending the launch last September—at the age of 94—Virginia was interviewed by Ladies of Landsat co-founder, Kate Fickas.

*USA Today/ MIT Tech/Science / launch 94- Kate Fickas*

**But if we jump back in time to 2004** when we started gathering names of Landsat veterans to interview, we had **a really difficult time finding out much about her.**

**Virtually nothing showed up in online searches.** We knew that she had headed the team at Hughes Aircraft Company that developed Landsat 1's Multispectral Scanner System.

We knew she was a past Pecora Award winner,
and we knew that Stephen Hall had interviewed her for his 1992 book "Mapping the New Millennium".

*Jump back, 2004, difficult time much about her, 0 online, Hughes, Pecora 1979, 1992 Stephen Hall*

But this **grainy photocopy of a photo** found in a Landsat history brochure created by, the commercial operator of Landsat in the mid-1980s, was the only photograph of her we could find.

*Photocopy, vets Hughes SBRC, section manager, 1999, crestfallen, continue to inquire OH*

Then, as we were setting up interviews with Landsat Veterans at the former Hughes Santa Barbara Research Center, where much of the early Landsat sensor fabrication took place, we got word from a section manager there that they had contacted Virginia's family in LA and had found out that she passed away in 1999.

Our team was crestfallen at having missed an opportunity to interview her, but we continued to inquire about her role in the oral histories we conducted with others.

Fortunately for us all, Darrel Williams, a co-author and the former L7 Project Scientist, was dogged in his pursuit of her. When we couldn't find an obituary, Darrel was determined to keep searching. And, in 2008, he turned to People Finder and found a phone number for a "Virginia T. Norwood" in the LA area.

*Fortunately 4 us all, Darrel, dogged pursuit, obit, determined to keep searching, 2008, People finder, "VTNorwood" LA, hiding plain sight/topanga, month later Pecora, 81, OH 1 of 2*

He dialed the number and Virginia picked up the phone.

She had been hiding in plain sight in her same home in Topanga Canyon where she'd lived in for decades.

A month later, at age 81, she joined us at Pecora 17 in Denver to record an oral history, the first of two she participated in with us.

SLIDE THREE

**"Gentlemen, that's a map" - The Marvelous MSS** #2

Virginia was an excellent engineer and gifted manager of people. She conducted an early user survey to get a good grasp of what was needed and where spectrally, the best information could be found.

*V excellent eng/ talented manager / user survey/ what was needed / where spectrally to look; in hand spaceborne multispectral instrument; first design like TM of L4/5, time tight, tech constraints, limited weight RBV, scaled back to MSS.*

With that information in hand, she set out to design a **spaceborne multispectral instrument.** The first design she came up with was much like the Thematic Mapper that flew on Landsats 4 & 5, but with time tight, technology constraints, and a very limited weight allotment on a spacecraft tailored for a Return Beam Vidicon primary instrument, she simplified her sensor concept into what became the MSS.

While we think of the MSS today as rudimentary, it was revolutionary for its time. Virginia's choice to use detector technology, send the data down digitally, and include onboard calibration, in many ways set the path for modern remote sensing.

*MSS rudimentary, revolutionary; detector tech, digitally, onboard cal; path for modern RS*

The MSS used a scan mirror, sweeping back-and-forth more than 13 times per second, as the satellite orbited to build up an image. That scan mirror was a moving part, what Stephen Hall referred to as the "bette noire of aerospace engineers" and It. Freaked out. Everyone. very few folks at NASA or USGS thought it was viable.

NASA geologist, Paul Lowman, pictured here, recalled in one of our oral histories, thinking "this crazy thing will never work."

And, the well-known USGS cartographer Alden Colvocorresses, known better as Colvo, was vocally dismissive of the MSS and its "little mirror in space" being of any use to cartographers.

Norwood even had her team take the MSS engineering model on a road trip to prove that it would work. This image of half dome—a copy of which still hangs on Virginia's wall to this day—is from that trip.

*MSS scan mirror, sweep, 13, build image, moving part, Hall Bette noire, Freaked Out Everyone, few folks at NASA or USGS thought it would work. Lowman. Colvo, "little mirror in space" Did work!*

As you all know, the MSS did work!

A favorite story captured during our oral histories was of the first image coming down:

A group gathered at NASA Goddard as the first MSS transmission was translated onto film and displayed to onlookers in black in white…. There were lots of clouds at first and then the first clear area appeared in SE Oklahoma. A circular pattern came into view and someone in the room fretted that there were moiré patterns…. But when they figured out the location, they realized they were looking at curving outcrops of the Ouachita (**waa** – shee-tuh) mountains.

Colvo, the vocal MSS critic, turned to those assembled in the room and remarked, "Gentlemen, that's a map"

He later wrote to Virginia to commend her on the MSS' success and to tell her that the MSS was "a real mapping instrument"

*Favorite story captured, MSS transmission translated film, clouds, clear SE OK, circular patterns, moire patterns, curving outcrops waa-shee-tuh; Colvo: map; commend MSS, "real mapping instrument"*

SLIDE FOUR

**A Record of Distinction, Getting Data Down #3**

Today, Landsats 8 and 9 bring down about 750 scenes a day each from across the planet. This is an amazing improvement over early Landsats that has been enabled by forty-plus years of technological advances.

When the first generation of Landsat satellites launched, they each carried two massive wideband video tape recorders that weighed 76 pounds each and carried 1800 feet of 2" wide tape and that's how they recorded data collected outside the US for later downlink to US receiving stations.

But all of the tape recorders failed before the sensors did. They were so unreliable in comparison to the rest of the spacecraft that they didn't even include them on Landsats 4 or 5 and instead relied on a satellite relay system, known as TDRSS, to get data down.

But L4 and L5 launched before TDRSS was fully operational.

So, the "Near-global landmass coverage" that had been a goal from the onset of the Landsat program, was nearly impossible, relying only on US Ground stations. And this history was etched into the US Landsat archive, as data gaps.

Fortunately, a network of International Cooperators built international ground stations to download data of their countries, and USGS has been able to partner with them to add their data they collected to the USGS archive… filling in many of those data gaps.

*L8/9 add 750/day EACH from across planet to US archive; amazing improvent, enabled 40+ yrs advances; 1st gen, wideband video tape recorders, 76, 1800' 2" record data collected outside US for later downlink to US receiving stations; all tape recorders failed before sensors, so unreliable in comparison to SC didn't even include them o L4/5, instead relied on satellite relay system, TDRSS, to get data collected outside of US receiving circles to the ground. L4/L5 launch before TDRSS fully operational/ so "near-global land mass coverage" goal onset, nearly impossible only US ground stations; that history was etched into US Landsat archive gaps, IC/ IGS, USGS partner, add, filling gaps*

SLIDE FIVE

**The Thematic Mapper, Complexity Squared and SWIR Wars** #4

As you have heard, Virginia Norwood conceptually designed a sensor very much like the Thematic Mapper that flew on Landsats 4 and 5, before designing the scaled-back MSS.

So, when Hughes bid on the TM build for L4 and 5, they were confident they could built it quickly and for a reasonable cost. But creating the increased spectral, spatial, and radiometric resolutions introduced many unforeseen technological challenges.

For instance, they had to use a bigger almost 21" scan mirror, and they used bidirectional scanning, collecting data in the forward and reverse, to increase TM dwell time.

With the exception of some of the technology for the thermal band, all of the hardware and technology for the TM was entirely new. So much so, that a Hughes engineer we interviewed referred to L4 and L5 as "flying laboratories."

There were so many problems and delays, that L4 launched 2 years behind schedule.

That the NASA Program Manager even threated to fly a dead weight mass model of the TM and just use the tried and tried MSS instrument at one point.

But Hughes overcame the challenges and deliver the TM in Feb. 1981 for integration

*As heard, Norwood conceptual TM, Hughes bid TM confident quick/reasonable, spec/spatial/radiometric res intro unforeseen tech challenges; 21" mirror/ bidirectional scanning=dwell; expection theral band, all tech new; so much so flying lab; prob 2 years behind sched. NASA PM, threatened to fly a dead weight /mass model TM / rely on MSS; did overcome challenges, delivered for integrations 1981.*

SLIDE SIX

**"Landsat D Will Fly… in July": Landsat 4 & 5 Design Challenges #5**

General Electric was both the spacecraft and ground system contractor.

They had to contend with all types of new mission constraints for the L4 and L5 satellites, including

+ a modular design
+ compatibility with shuttle retrieval for in orbit repair and refueling (including a lower orbit and more consumables/fuel for orbit adjustments needed to rendezvous with the shuttle)
+ a 12.5' TDRSS boom and antenna

That TDRSS antenna introduced enough jitter to impact TM pixel geolocation and a special altitude displacement sensor had to be developed to measure the vibration and send it down with other housekeeping telemetry.

And L4 & L5 were also the first civilian satellites to carry a GPS receiver package to help assess if GPS would deliver more accurate positioning information than ground-predicted ephemeris.

But despite all of this, the six-fold data transmission increase of the TM was a major system driver.

The cost of the Landsat D program ended up more than quadrupled, going $30 million to over $140+ million.

But there was a silver lining:

+ that extra fuel onboard L5 for the non-realized shuttle retrieval,
+ coupled with lessons learned on orbit from L4
+ and a highly talented flight ops team…

helped Landsat 5 operate for 29 years and sustain Landsat data record through the failed launch of L6…earning itself a Guinness World Record.

*General Electric contractor for L4 and L5 spacecraft and ground system; all kinds of mission constraints, modular design, compatible with shuttle/lower orbit fuel; 12.5" TDRSS/ jitter/ TM geolocation/ alt disp sensor/vibration/ L 4 & L 5 1st civilian sat GPS receiver package, access position info/ground-predicted ephemrics; Despite all this, TM 6-fold data increase of MSS was system driver. L4/5 program cost quadrupled, $30M to $140M+; silver lining: extra fuel, lessons learned on orbit for L4, and highly talented flight ops team (pecora award this meeting)…. L5 29 years*

SLIDE 7

So, I've only just scratched the surface of the history and fascinating stories that are captured in Landsat's Enduring Legacy, tonight. There is much, more in those pages,

And, even for these five facts shared with you tonight, there was so much I had to cut out to fit the time constraints of this talk.

But I wanted to leave you with this image: Landsat satellite in orbit servicing may happen after all. This It's an artist's conceptual rendering of the upcoming OSAM-1 satellite refueling L7 in orbit.

For anyone interested in learning more about OSAM-1, there is a recent podcast that I can recommend.

And for those interested in more details of Landsat's long history, I encourage you to download a copy of the book.

Thank you and good evening.

*Only stratches, so much more in pages, even this talk, but leave you with this, on-orbit satellite servicing might happen after all, OSAM-1 pod cast, Landsat long history recommend download the book.*