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The next Landsat: Mission turning point?

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A R T I C L E I N F O

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A B S T R A C T

For over fifty years, the Landsat satellite series has provided continuous and comprehensive data for monitoring changes on the Earth's terrestrial surface. Eight successive missions, carrying progressively more sophisticated sensors, with improved radiometric, geometric, and spatial characteristics, have provided an unbroken series of optical and thermal imagery, unparalleled globally. With limited lifetimes for each Landsat satellite, planning of each mission typically overlaps to ensure continuity. Commencing in 2021, planning of a Landsat-9 successor gathered user needs from across the Earth Observation (EO) community, resulting in the Landsat Next (LNext) mission design of three sun-synchronous satellites to acquire reflective and thermal wavelength observations with two to three times the temporal, spatial, and spectral resolution of previous missions. Proposed 2026 U.S. budgets have significantly reduced NASA Earth Science funding. Alternate architectures are now being investigated for Landsat Next that would only meet Landsat-9 design requirements. While this would provide observation continuity, this implies a revised Landsat Next program launched in the early 2030s with nearly 30 year old capabilities, that may acquire data with lower radiometric quality than the current on-orbit Landsat-8 and 9 missions, and that will not support the new capabilities advocated for by the EO user community. This correspondence serves to raise community awareness that the decision is pending, and outlines the observation requirements originally envisioned for LNext and how they were derived to provide context for evaluating the restructured and descoped capability now being considered.

1. Introduction

The Landsat satellites provide the longest record of space-based Earth Observations (EO) that started in 1972 with the Multispectral Scanner on Landsat-1. Eight Landsat satellites carrying progressively more sophisticated sensors from the Thematic Mapper, Enhanced Thematic Mapper Plus, to the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), have provided 50+ year observation continuity (Roy et al., 2014, Masek et al., 2020). Landsat has established capabilities for mapping and monitoring land cover, land surface biophysical and geophysical properties, and for managing and monitoring land, water, and coastal resources (Wulder et al., 2022; Radeloff et al., 2024). Landsat data provide a balance between the requirements for localized medium-spatial resolution studies and global monitoring. The temporal depth of the Landsat archive is unique in providing a multi-decadal baseline to compare past and future change against. The impacts of

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Landsat are well documented. Based on the number of published works, the Landsat program made a larger scientific contribution as of 2022 than any other EO program (Wulder et al., 2022). The economic benefits of Landsat are also significant. Landsat provided $3.45 billion economic benefits in 2017 (Straub et al., 2019) that increased to $25.6 billion in 2023 not including the value derived from users accessing Landsat data indirectly through commercial and cloud-based providers (Loomis et al., 2024). These economic benefits significantly eclipse Landsat mission costs (NASEM, 2024).

Landsat is managed as a partnership between the National Aeronautics and Space Administration (NASA) and the Department of the Interior (DOI) U.S. Geological Survey (USGS). NASA is responsible for the system engineering and design, developing the flight segment, securing launch services, flight ground systems integration, and conducting on-orbit initialization and verification, and the USGS is responsible for the ground system development, data processing, archiving, product generation and distribution (Loveland and Dwyer, 2012; Roy et al., 2014; Crawford et al., 2023). External advice is provided by advisory committees including the Landsat Advisory Group (LAG), a subcommittee of the National Geospatial Advisory Committee (NGAC), and by the Landsat Science Team (LST). The LAG is composed of NGAC members and external remote sensing experts, appointed by the NGAC Chairperson, in accordance with the Federal Advisory Committee Act and the Geospatial Data Act (Folger, 2018). It is tasked with providing non-binding recommendations to the DOI on Landsat program priorities and policy matters in response to requests from agencies such as the USGS. The LST is composed of scientists and engineers from academia, U.S. Federal agencies, and includes representation from non-U.S. institutions, that together ensure a broad range of perspectives, and is selected typically every five years through a competitive proposal review process (Roy et al., 2014). Past LSTs have been directed to provide feedback to NASA/USGS on the data systems, product formats and contents that may affect Landsat users, that support integration with past Landsat data, and enable new applications; the interoperability of Landsat with other planned and on-orbit remote sensing systems including notably the European Copernicus Sentinel-2 satellite series (Drusch et al., 2012); and, the observation requirements and functional performance specifications of each upcoming Landsat mission. NASA and USGS have mobilized and gathered information at key decision points regarding mission updates and significant changes with advice from four LSTs. This correspondence is authored by members of the most recent 2018–2023 LST.

In recognition of the need for Landsat continuity, the U.S. Sustainable Land Imaging (SLI) Program committed in 2016 to extend the Landsat record from the currently on-orbit Landsat-8 and 9 systems with the follow-on Landsat Next (LNext) mission (NASA and DOI, 2016). Landsat-8 and 9 were launched successfully in 2013 and 2021, respectively, and carry similar sensors developed in the early 2000s, and Landsat-9 has 10 years of consumable resources and a 5-year sensor design life (Masek et al., 2020). The U.S. Congress provided funds to initiate LNext with costs equivalent to Landsat-8 when adjusted for inflation (Newman, 2022) and the Raytheon Company was selected in June 2024 to build the system (CRC, 2025). The LNext mission was designed to meet evolving user application and science needs with two to three times the temporal, spatial, and spectral resolution provided by Landsat-9 and simultaneous acquisition of reflective and thermal wavelength observations. LNext has a nominal 2031 launch, consisting of three polar-orbiting satellites carrying the same sensors to increase the frequency of observations and provide redundancy in case of individual sensor failure, and will acquire an order of magnitude more data than Landsat-9.

Given significant proposed 2026 U.S. budget reductions, alternate LNext mission architectures are now being investigated. On 11 March 2025, the NASA Transition Authorization Act of 2025 was introduced, which directed NASA to assess aspects of the Landsat missions that could be provided by private sector data-buys or service procurements that ensure data quality and continuity while maintaining open access and long-term archiving (NASA, 2025). Commercialization raised concerns due to the potential for reduced independent oversight (Roy et al., 2025) and because the previous commercialization of Landsat was not successful (Markham et al., 2017) including greatly reduced on-orbit capability (Goward et al., 2017). On 15 August 2025, new and restructured LNext requirements were disseminated (NASA SLI, 2025). This was unexpected. The restructured requirements are descoped in budget and capability to a single satellite with sensor characteristics and performance similar to Landsat-8 and 9. While such a system would ensure observation continuity, this would mean by the early 2030s the Landsat program will have a sensing capability that will be three decades old. The final LNext architecture decision has not yet been made. This correspondence serves to raise community awareness that the decision is pending, and outlines the observation requirements originally envisioned for LNext and how they were derived to provide context for evaluating the restructured and descoped capability now being considered.

2. Landsat next observation requirements assessment

The LNext observation requirements were based on current medium-resolution global coverage land imaging capabilities (the Landsat-8 and 9 and Sentinel-2 systems) and assessments of current and future needs to support and advance science and applications. It is beyond the scope of this correspondence to describe all the assessments, rather the main elements are summarized below. Notably, before LNext was initiated, the 2012–2017 LST provided recommendations on observation priorities for missions after Landsat-8. These recommendations helped to shape definitions of “breakthrough” and “ideal” observation capabilities, particularly in areas including increased observation frequency and reduced latency, enhanced spatial resolution, expanded spectral capabilities and interoperability with Sentinel-2, and included endorsement of the need for long-term continuity of the Landsat archive and generation of higher-level derived products (Roy et al., 2014).

2.1. USGS and LAG assessment of user needs for Landsat missions after Landsat-9

The USGS managed and undertook 379 interviews with Landsat users from U.S. civil (not defense or geospatial intelligence) federal agencies to survey future needs. User perspectives from 157 agriculture, ecological and land change science, forestry, geological, natural hazard (floods, fire and volcano), water, and cryosphere subject matter experts were obtained. Structured interviews were used to collect information focused on three core attributes: spatial resolution, cloud-free observation frequency, and spectral characteristics. Each attribute was categorized across three levels: minimum (the current Landsat-8/9 capability), breakthrough (substantial improvement), and ideal (unconstrained by current technology or cost). The study and results are reported in Wu et al. (2019), and the key findings are summarized below.

The survey respondents indicated unambiguous support for the continuity of free, open-access, Landsat-like medium resolution satellite data. Users cited 10-m resolution and weekly cloud-free observations as “breakthrough” thresholds for many applications. The addition of red edge bands and multiple narrower bands in the visible, near-infrared (NIR), shortwave infrared (SWIR), and new thermal infrared (TIR) bands, were frequently requested. Ideal needs included many 10 nm spectral resolution bands in the 400–2500 nm range and increased TIR sensing capability. Users desired at least the 100-m TIR resolution provided by Landsat-8 and 9, with 30-m and 10-m TIR resolutions as breakthrough and ideal thresholds respectively, to enable fine-scale agricultural, natural hazard, and cryospheric applications.

In addition to the structured interviews, Wu et al. (2019) summarized complementary LAG outreach to gather user needs from non-federal, non-LST stakeholders, including commercial industry, non-profit, and international organizations, state and local governments, and academia (LAG, 2016). There was strong alignment between the federal civil user community and the LAG findings on the importance of both Landsat continuity, and improvement needs for future missions. The LAG recommended that future missions include 10-m resolution (including for TIR observations), sub-weekly revisit, additional spectral bands for cloud/aerosol/ice detection, and interoperability with Sentinel-2 (LAG 2018).

2.2. Draft LNext sensor requirements and mission architecture design options and LST response

Draft LNext mission sensor requirements and satellite architecture options were developed by NASA to meet the aforementioned user needs, earlier LST recommendations, and expert feedback gathered from targeted review panels (agriculture, cryosphere, vegetation, ecology, inland and coastal water, temperature and emissivity, evapotranspiration, atmospheric correction and cloud masking) that included select LST participants. Draft requirements and architecture options were presented to the 2018–2023 LST for discussion and feedback and are summarized below.

2.2.1. Sensor requirements

The draft LNext requirements were for a super-spectral sensor acquiring 25 spectral bands (410 nm to 12,000 nm) with four 10-m bands in the visible and NIR, twelve 20-m bands predominantly in the SWIR, eight 60-m bands predominantly in the TIR, and a 30-m short wavelength blue (coastal aerosol) band, maintaining the radiometric resolution of the Landsat-9 OLI-2 and slightly improved TIRS-2 radiometric resolution. Observations from all bands were to be acquired within 20 s for any location. These capabilities were endorsed by the LST because (i) they provide continuity with previous Landsat mission capabilities (Roy et al., 2014; Masek et al., 2020), (ii) the radiometric quality matches or improves on Landsat-9, (iii) they complement the Sentinel-2 reflective wavelength bands (Drusch et al., 2012), and (iv) they enable new science and applications. The LST noted that coincident acquisition of visible, NIR and SWIR (VSWIR) observations is essential to provide continuity with previous Landsat missions (Wulder et al., 2022), and that simultaneous VSWIR and TIR observations are needed to allow direct comparison of reflected and emitted radiation for applications including accurate evapotranspiration assessment (Anderson et al., 2012) and improved cloud detection (Qiu et al., 2019). The draft signal to noise (SNR) characteristics for the VSWIR bands were set as for Landsat-8 OLI (when aggregated to 30-m) (Knight and Kvaran, 2014). While acknowledging possible implications in design trade studies, the LST emphasized the need for higher SNR values, such as for the shorter wavelength visible bands to ensure reliable retrieval of aquatic parameters and discrimination among land cover categories (Schott et al., 2016). The LST recommended that reflective band saturation (e.g., over bright reflective land surfaces or due to specular reflectance over snow and ice) should be avoided, and that dual-gain approaches to maintain SNR at low radiance without saturation at high radiance were acceptable.

The draft LNext temporal resolution requirements were for nadir observations acquired over the same location at least every 16 days. The LST strongly recommended an improved revisit as many applications require frequent observations and because for most of the recent history of Landsat there have been two satellites on-orbit providing 8-day revisit. Users require usable cloud-free data at specific intervals, not just frequent satellite overpasses. This distinction is critical because persistent cloud cover and strong cloud seasonality (e.g., in tropical or boreal regions) reduce surface observation frequency. This motivates, for example, the NASA Harmonized Landsat and Sentinel (HLS) data set (Ju et al., 2025), although combination of Landsat and Sentinel-2 data does not provide improved TIR temporal resolution as the Sentinel-2 satellites do not carry thermal sensors.

The draft geolocation requirements for the highest accuracy Level 1T data, derived using ground control and digital elevation model (DEM), were expressed as geodetic 90CE (circular error 90th percentile) pixel uncertainties of 8-m, 9-m, 11-m, and 21-m for the 10-m reflective, 20-m reflective, 60-m reflective, and 60-m TIR bands, respectively. The LST noted that ideally, satellite data should have geolocation accuracy better than 0.5 pixels for all bands to support time series analysis and change detection, although this may be constrained at 10-m resolution by the availability of sufficiently high resolution global DEM data.

2.2.2. Draft mission architecture options

Single and constellation LNext satellite architecture options were presented to the LST. To date, single Landsat satellites have been launched at infrequent intervals (e.g., the gap between Landsat-8 and 9 was 8 years). The LST was strongly supportive of mission architectures that would provide redundancy in case of individual satellite failure and increase temporal observation frequency. Constellation options composed of several satellites on-orbit carrying the same instrumentation were presented, categorized as “mixed” (satellites in orbits with different inclinations, altitudes, and ascending node longitudes, providing different swath configurations that change in space and time), “spaced” (satellites following each other 10s to 100 s of minutes apart in the same orbit track so that their individual swaths are sensed on the same day but are located geographically apart east-west), and, “string-of-pearls” (satellites following each other at short interval in the same orbit track so that their individual swaths abut across-track and are sensed nearly simultaneously).

The “mixed” constellation option was not favored by the LST because the temporal cadence and spatial coverage of the data would be highly variable, causing complex bi-directional reflectance (BRDF) effects due to very different solar and viewing geometries, and the different overpass times would reduce the consistency of thermal applications due to diurnal surface temperature variations. The “spaced” and “string-of-pearls” options were preferred. Both could provide narrow field of view sensing (e.g., comparable to current Landsat-8 and 9 or Sentinel-2) meaning that BRDF issues would be less severe and could be corrected (Zhang et al., 2018). The LST highlighted the need to ensure that calibration uncertainties within the constellation sensor data do not exceed heritage Landsat-8/9 cross-track uniformity. The LST noted that the constellation options could complicate processing, archiving, and distribution of data, but that observations are increasingly being provided as tiled Analysis Ready Data (ARD), as opposed to “scene-based” images. By the 2030s, ARD formats are expected to be prevalent, mitigating concerns.

2.2.3. Directed request for information (RFI) questions

The LST submitted its recommendations in a November 2020 response to a U.S. government RFI that also included directed questions, summarized briefly with the LST responses below.

2.2.3.1. Increasing the spatial resolution of a 1610 nm SWIR band from 20-m to 10-m. The draft sensor requirements were four 20-m SWIR bands, a 1610 nm band (based on heritage from the Landsat SWIR 1 band) and 2100, 2210 and 2260 nm bands (based on heritage from the Landsat SWIR 2 band). The LST supported increasing the spatial resolution of the 1610 nm band from 20-m to 10-m to complement the three visible and the broadband NIR 10-m LNext bands, and, to enable spatially detailed crop, soil moisture, forest, and burned area monitoring.

2.2.3.2. Adding an off-nadir along-track pointing camera covering the visible spectral region with 60-m resolution. The LST endorsed this concept, noting the heritage for along-track pointing for improved cloud detection, cloud height retrieval, and aerosol optical depth characterization from the NASA Multi-angle Imaging SpectroRadiometer (MISR)

(Marchand et al., 2010), and that atmospheric characterization at the time of Landsat overpass will benefit atmospheric correction.

2.2.3.3. Adding a mid-wave infrared (MWIR, 3.9 μm) band. The LST noted that, with TIR bands, this would enable active fire detection, mapping of volcanic activity, and retrieval of fire radiative power (FRP), and improve cloud masking over snow and ice. Although desirable, this was considered a low priority because fire monitoring benefits most from many observations every 24 h (such as from the MODIS Terra and Aqua satellites). The LST also noted that if a MWIR band were included, then an appropriate balance between spatial resolution and radiance sensitivity to resolve cool smoldering and hot flaming fires (Wooster et al., 2021), be considered.

2.2.3.4. Adjusting the equatorial crossing time from 10:00 am to 10:15 am to better align with the 10:30 am Sentinel-2 crossing time. The LST supported this noting that this adjustment is within the variation of past Landsat crossing times, and that a 15 min later crossing time will cause the solar zenith angle at the time of overpass to be lower, reducing the length of shadows and BRDF effects (Zhang and Roy, 2016). The LST recommend that the equatorial crossing time be restricted to vary by no more than ±15 min, as with recent Landsat missions.

3. Comparison of the Landsat Next and the restructured / descoped missions

3.1. LNext

NASA finalized the LNext design in 2024 as a constellation of three satellites each carrying identical sensors acquiring a 164-km swath (±7.2° from nadir) with 26 VSWIR and TIR bands. The satellites are in the same sun-synchronous, ~98° inclination, 653-km altitude orbits with 10:10 am ±5 min equatorial crossing times, and placed 120° apart to provide global land coverage every 6 days. The spectral bands build upon the Landsat legacy, complement Sentinel-2, and have heritage from other sensors (Supplementary Table 1, Fig. 1). In comparison to Landsat-8/9, there are 15 new bands proposed for LNext that will enable new and improved applications including water quality and aquatic health assessments, crop production and soil conservation, vegetation monitoring, forest management and monitoring, weather and snow dynamics research, and mineral mapping (Bair et al., 2023; Bramich et al., 2021; Dennison et al., 2023; Ford and Vodacek, 2020; Li et al., 2025; Portela et al., 2025). In addition, new bands to better characterize aerosols and atmospheric water vapor at the time of observation will improve atmospheric correction and low-latency processing compared to current Landsat capabilities that depend on the availability of MODIS (and after MODIS end of life, VIIRS) atmospheric characterization data

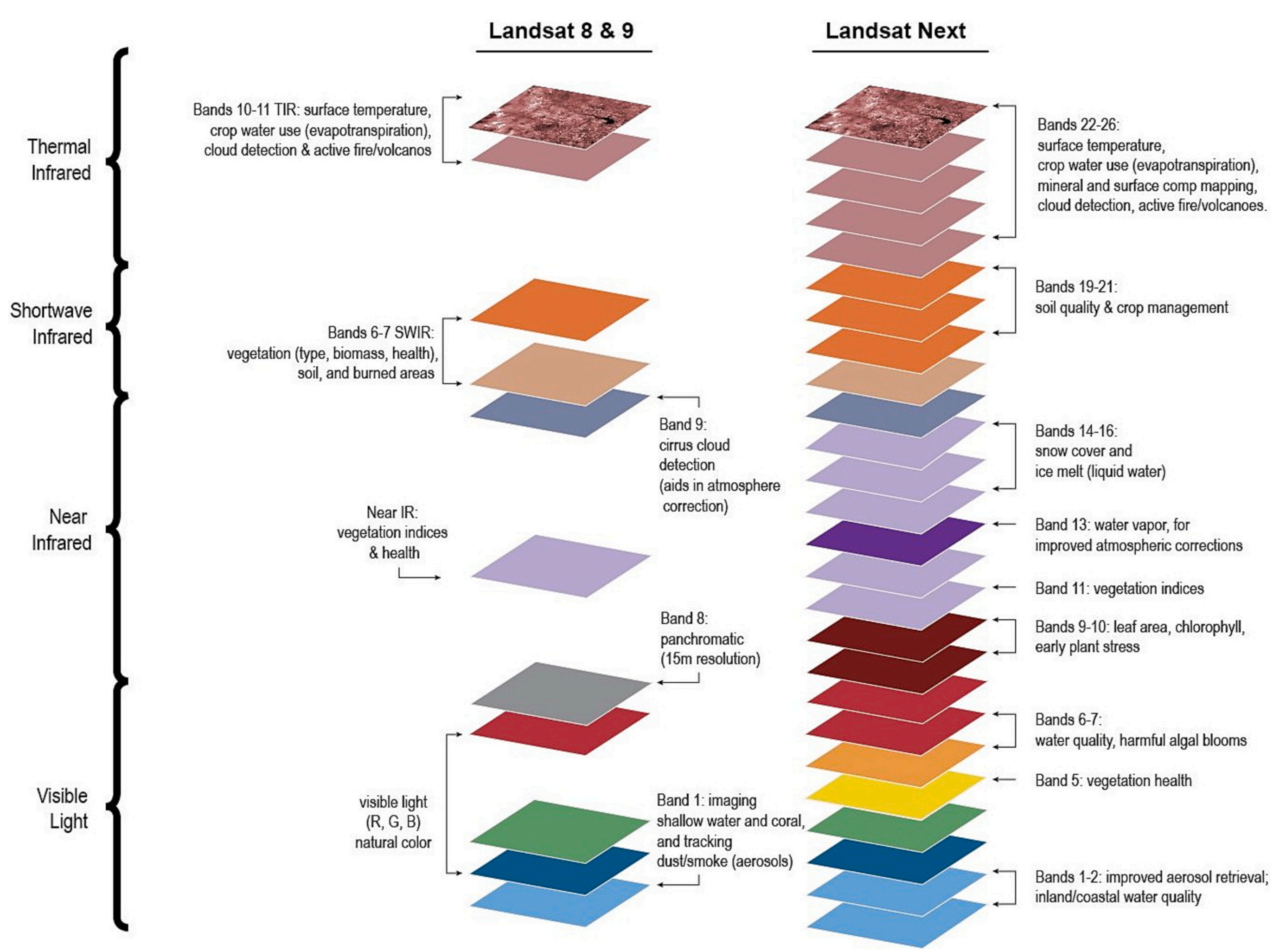

Fig. 1. Comparison of Landsat-8 and 9 spectral bands with Landsat Next, with select applications identified. The Landsat-8/9 bands are 30-m except for the two TIR (60-m) and the single panchromatic (15-m) band. The Landsat Next bands are 10-m or 20-m, except for the five TIR bands, and the cirrus band 17, water vapor band 13, and violet band 1, that are 60-m (see supplementary Table 1). Image credit: NASA. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Crawford et al., 2023). New and 60-m TIR bands will enable improved land surface temperature and new emissivity estimation using multi-TIR band temperature and emissivity separation algorithms (Malakar et al., 2018). The VSWIR bands will have SNR performance set as the Landsat-8 OLI, and the TIR bands will have Noise Equivalent Delta-Temperature (NEΔT) performance comparable to the Landsat-9 TIRS-2. The radiometric resolution will vary among bands from 12 to 15 bits **(**Eon et al., 2025**)**. The Level 1T geometric accuracy is at least 8-m (90CE) to support change detection and detailed mapping using the four 10-m bands.

3.2. Restructured / descoped mission

Due to the aforementioned budget cuts, the restructured mission now being considered is a single satellite with sensor characteristics and performance between those provided by Landsat-8 and 9 (Supplementary Table 2). The restructured requirements (NASA SLI, 2025) state that the "… *data acquired over the entire mission lifetime need to be sufficiently consistent with operational Landsat-9 data requirements, in terms of acquisition geometry (sensor view angles < 7.5 degrees), revisit rates, calibration, coverage characteristics, spectral and spatial characteristics, radiometric performance/stability, output product quality and data availability, to enable and sustain long-term, consistent detection and quantitative characterization of changes on the global land/water surface*." Most immediately this means that in the 2030s, when Landsat-9 reaches its end of life, the restructured mission would provide observations with only a 16-day temporal revisit which contradicts the recommendations of the USGS user survey, LAG, and the 2012–2017 and 2018–2023 LSTs.

The restructured TIR band spatial and spectral (minimum, central, and maximum wavelength) resolutions are the same as Landsat-9 TIRS-2, and with noise equivalent delta temperature (NEΔT) at 300 K requirements that are comparable to the Landsat-9 TIRS-2 pre-launch requirements described in Masek et al. (2020). The restructured VSWIR band spatial and spectral resolutions are also the same as for the Landsat-9 OLI-2 (Masek et al., 2020) and also similar to Landsat-8 OLI-1 (Knight and Kvaran, 2014). The restructured VSWIR SNR requirements are from 1.88 (Coastal/Aerosol band) to 3.35 (SWIR2 band) times better than the Landsat-9 pre-launch OLI-2 SNR requirements reported in Masek et al. (2020). Notably, however, the Landsat-8 OLI, Landsat-9 OLI-2 and TIRS-2, on-orbit performances significantly exceeded their pre-launch requirements (Morfitt et al., 2015; Micijevic et al., 2022; Barsi et al., 2022). Thus, there is a risk that the restructured mission on-orbit, particularly given the need to reduce costs, could meet its pre-launch requirements but provide observations with lower radiometric quality than currently provided by Landsat-8 or 9. The restructured Level 1T geometric accuracy requirement is 5-m (90CE) which, while welcomed, is high when considering the 100-m and 30-m restructured mission TIR and VSWIR band spatial resolutions, respectively.

4. Summary

The Landsat program has evolved from demonstration of the first dedicated land EO satellite to the present status of a U.S. flagship program of record, with technology improvements and lower satellite launch costs enabling successively improved mission capabilities. The Landsat program has maintained substantial investment in radiometric calibration and characterization (Markham et al., 2017), providing reference imagery that have been used to improve and inform commercial satellite development and applications. Recent Landsat collection-based reprocessing, improved geolocation, and global surface reflectance generation, provide a consistently processed, multi-decadal record (Crawford et al., 2023). The science grade quality of the Landsat data supports global change science and a broad user base of U.S. and international land and water, management, decision-support, and monitoring applications (Wulder et al., 2022; Radeloff et al., 2024).

The design and development of EO systems necessitate balancing engineering, technological, and budget constraints, against current and future observation requirements, all while factoring in the lead time to develop and launch a system with respect to evolving capabilities. LNext was designed by NASA to meet current and future user needs that were assessed comprehensively, including (i) a USGS survey of U.S. federal agency users, (ii) LAG input to broadened the survey scope to commercial industry, non-profit, international organizations, state and local government stakeholders, (iii) directed discussions with targeted expert review panels, and (iv) input from the two previous LSTs including 2018–2023 LST feedback on draft sensor requirements and mission architecture options.

The selected LNext design, a three-satellite constellation providing 6-day global revisit with 21 VSWIR bands at 10/20-m resolution and 5 TIR bands at 60-m resolution, is envisioned as the centerpiece of the U.S. SLI Program for the 2030s. It would continue the 50+ year Landsat record and enable:

- new and improved applications including crop production and soil conservation, rangeland management, water quality and aquatic health assessments, forest management and monitoring, weather and snow dynamics research, and mineral mapping,
- comparison of simultaneously acquired 60-m TIR and 10/20-m VSWIR radiance, for improved evapotranspiration and water use assessment, cloud detection, and predictive land surface modelling,
- synergy with Sentinel-2 data (available since 2015) and the planned next generation Sentinel-2 data, that have no TIR capability,
- low-latency and improved surface reflectance and land surface temperature and emissivity estimation,
- observation continuity in the case of within-constellation sensor failure,
- increased temporal revisit to increase the likelihood of acquiring observations free of atmospheric contamination (e.g., cloud, haze, and increasingly, smoke) enabling improved monitoring, attribution and dating of surface change of importance to agricultural applications (crop status, yield prediction, harvesting; water use), burned area mapping, water quality assessment, and cryosphere dynamics, as examples.

Sustained space-based observations are critical for the delivery of science and decision-support information, with local, national, and global utility (KISS, 2024). However, as for previous Landsat missions (Goward et al., 2017), the reliance on governments to fund EO systems and data archives is not guaranteed. Substantial year 2026 U.S. budget proposals may reduce LNext funding and alternate architectures are now being investigated that only meet the minimum capabilities of the existing Landsat-9 mission. While this would ensure observation continuity, it would mean by the early 2030s the Landsat program will have (i) a sensing capability that will be three decades old, (ii) may acquire data with lower radiometric quality than the current Landsat-8/9 missions, and (iii) meet none of the aforementioned new capabilities that have been advocated for to meet future user needs and that have established economic, societal, and scientific value. The final architecture decision for LNext has not yet been made. The U.S. Congress recently introduced bills that direct NASA to maintain LNext funding, architecture and sensor specifications, as well as build and launch schedules (U.S. Senate, 2025; U.S. House of Representatives, 2025). Decisions made now regarding the Landsat-9 successor will either advance, or constrain, Landsat's scientific and operational capacity throughout the 2030s and forward.

CRediT authorship contribution statement

David P. Roy: Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Michael A. Wulder:** Writing – review & editing, Writing – original draft. **Noel Gorelick:** Writing – review & editing. **Matthew Hansen:** Writing – review & editing. **Sean Healey:** Writing – review & editing. **Patrick Hostert:** Writing – review & editing.

Justin Huntington: Writing – review & editing. **Volker C. Radeloff:** Writing – review & editing. **Ted Scambos:** Writing – review & editing. **Crystal Schaaf:** Writing – review & editing. **Curtis E. Woodcock:** Writing – review & editing. **Zhe Zhu:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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Data availability

No data was used for the research described in the article.

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