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Remote sensing innovation: progressing sustainability goals and expanding insurability

01 Executive summary
02 Key takeaways
04 Innovation in remote sensing
11 Demand drivers in insurance
17 Enterprise-scale deployment in insurance
21 Conclusion

Executive summary

Recent innovations have supported the commercial adoption of remote sensing.

Applications of geospatial and earth observation sensor data from satellites, aircraft and drones are expanding rapidly. New business models are emerging as a broad range of solutions and services enabled by such data are unlocked across industries. The advent of start-ups taking advantage of better technology and substantial reductions in the cost of launching satellites will make such services even more accessible. This will democratise granular geo-physical insights beyond military and government to benefit also commercial enterprises, including insurers.

Remote sensing can play a wider role beyond industrial application: it can help build sustainable society.

Further, intergovernmental efforts towards building sustainable societies are gaining traction and remote sensing can play a key role in providing better data to measure sustainability indicators. High resolution (spatial and temporal) earth observation (EO) data can quickly and frequently reveal on-ground changes relevant for the UN's Sustainable Development Goals (SDGs), and help in optimising allocation of resources to accelerate progress. We estimate that at least 17% of the UN's 231 SDG indicators can immediately benefit either directly or indirectly from the use of EO data, and expect this to increase over time.

Rapid damage assessment and parametric product development are early use cases for insurance.

In insurance specifically, the trends can have far reaching implications for insurers and insureds. Remote sensing will enable new markets and risk pools, and ease existing processes such as claims assessment and, in time, underwriting and risk monitoring. Insurers will get better at leveraging high-frequency data from sources like synthetic aperture radar (SAR), combined with other sources (both ground and air). We will likely see multiple use cases with varying degrees of success across business lines. While challenges such as establishing accurate correlations between satellite data and actual losses have hindered widespread adoption, insurers will increasingly address these challenges by experimenting with hybrid modelling approaches, accessing better data and advanced data integration techniques.

Vendors and services in the remote sensing arena offer a wide variety of data and technologies.

Advancing machine-learning techniques and integrating multi-sensory, multi-source and multi-temporal data is key to plug data gaps and enable granular risk and loss insights for insurers. However, the diversity of data sources has raised several questions regarding cost, coverage, predictive power, regulation and challenges of integrating them across different risk pools and geographies. As a result, commercial data and satellite vendors have started to offer customised offerings to insurers. These are vertically-integrated packaged solutions, starting from launching a satellite to capturing the data and delivering the final analysis.

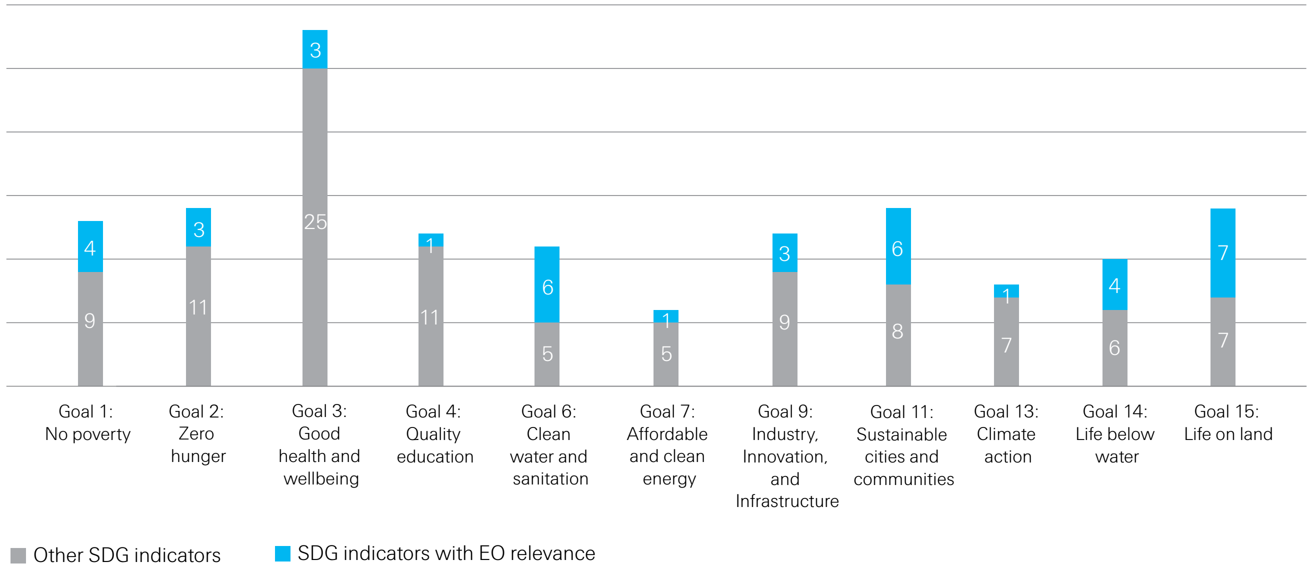
Data from multiple providers via open Application Programming Interfaces (API) may be combined to enable different business models.

In the future, insurers will operate in an environment where they will need continuous access to many different data sources, including from remote sensing. This is a strategic issue, taking insurers beyond their existing value chain. No single firm or marketplace currently provides all these sources of data. While many data vendors focus on extraction and distribution of data, few concentrate on data curation and refinement. We expect that this will give rise to specialised aggregators focused on integration and curation. The more integrated and refined the data, the wider the service offering to a customer. This emerging data ecosystem has many implications for the insurance industry, in particular the need for modular products, and better distribution.

Key takeaways

Remote-sensing-enabled earth observation (EO) can support progress towards the UN Sustainable Development Goals (SDGs): EO data for vegetation cover, habitation patterns and hydrometeorology can be merged with ground surveys and other Big Data to create synthetic maps providing granular insights on progress towards different SDG indicators. We estimate that progress towards at least 17% i.e. 39 out of 231 SDG indicators could benefit by direct or indirect use of EO data.

Collection of UN SDG indicators with earth-observation relevance



Source: United Nations, European Space Agency, Swiss Re Institute

Remote sensing can expand the bounds of insurability to new risk pools and make insurance processes more efficient across different lines of business (LoB). Examples of insurance processes that can benefit are granular indices for parametric products, rapid claims assessment and early warning alerts. By expanding the scope of insurability, remote sensing will make households and business more resilient.

Link to the UN SDGs	Line of business	Value chain	Use case	Remote sensing technology	Challenges	Benefits
	Agriculture	Claims assessment	Crop yield estimation to assess and settle claims.	Smart sampling enabled by both passive and active (SAR) remote sensing.	Establishing correlation between remote sensing vs historical yield data.	Less manpower required to estimate yields. Reliable sampling and cost saving.
	Property	Claims assessment	Rapid damage assessment after large scale flood events.	Flood maps enabled by both passive and active (SAR) remote sensing.	Measuring peak flood height and time for which water stands still.	Faster decisions on claim admissibility and settlement. Better reserving and lower moral hazard.
	Property	Underwriting and claims assessment	Detecting severity of roof and building structure damage.	Passive (aerial) imagery analysed with semantic segmentation.	Aerial imagery can be costly and difficult to acquire at short notice.	Faster underwriting. Better reserving and lower moral hazard.
	Property	Claims assessment	Subsidence loss assessment and prediction for sinking structures.	Active (Differential Interferometric Synthetic Aperture Radar or D-InSAR) images analysed over long time.	Hard to achieve higher temporal resolution across different generation of satellites.	Faster decision on claim admissibility and settlement.
	Agriculture	Product development	Crop parametric product for drought risks based on soil moisture index.	Passive (microwave) images to measure soil moisture levels.	More customisation required for adjusting the index to crop type and sowing stage.	Automated underwriting and payout. More comprehensive than Normalized Difference Vegetation Index (NDVI) and rainfall index.
	Property	Product development	Property (Flood) parametric product based on excess rainfall index.	Passive remote sensing images combined with data from ground-based weather stations.	High basis risk. Not suitable for single location risk and retail customers.	Affordable product with automated underwriting and payout. Longer time series of weather data.

Note: Passive sensors observe objects illuminated by sunlight or self-illuminated objects. Active sensors emit energy (radio, sound & light waves) to illuminate objects and they can operate in night and all-weather conditions.
Source: Swiss Re Institute

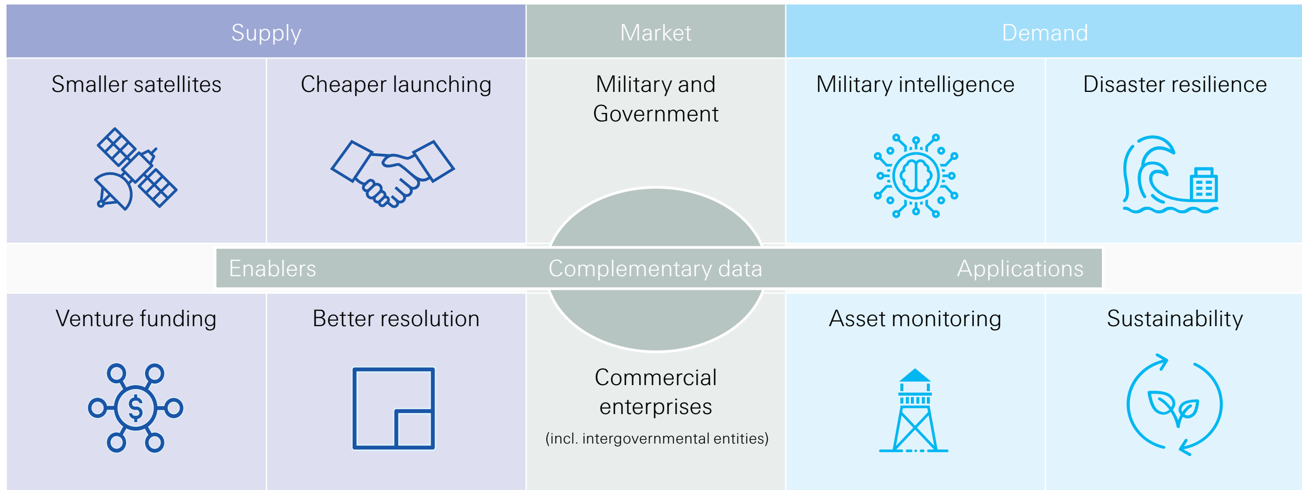
Innovation trends in remote sensing

Supply side and economic factors driving adoption

Innovation and commercialisation is making remote sensing more accessible.

Remote sensing, which includes both space and earth observation (EO), is the science of collecting and interpreting visual intelligence about objects from afar using sensors mounted on satellites, aircraft and drones. Military and governments have been the main users of remote sensing but with the technology becoming more affordable, supply-side developments are democratising EO across the private sector also. Innovation and commercialisation have accelerated launches of remote sensing satellites in recent years and expanded the range of applications in earth observation, which is our focus in this report.

Figure 1
Remote sensing market dynamics

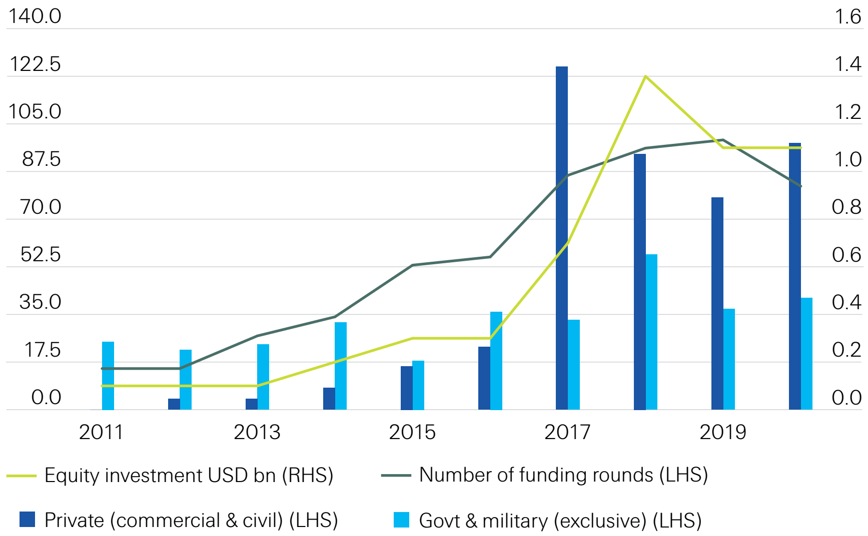


Source: Swiss Re Institute

The number of commercial remote sensing satellites in service has grown rapidly...

The sector is at an inflection point, given advances in satellite (miniaturisation) design and availability of cheaper commercial launching services. Component makers now offer packaged manufacturing and engineering services, which have enabled modular component design and quicker assembly of smaller satellites. The number of active commercial remote sensing satellites has outpaced growth in government satellites since 2015 due to increased affordability and equity investment. This has enabled application of remote-sensing technology to areas well beyond traditional end-customers and industries (see Figure 2).

Figure 2
Growth in number of remote sensing satellites by end user (LHS); growth in equity investment, USD bn (RHS)

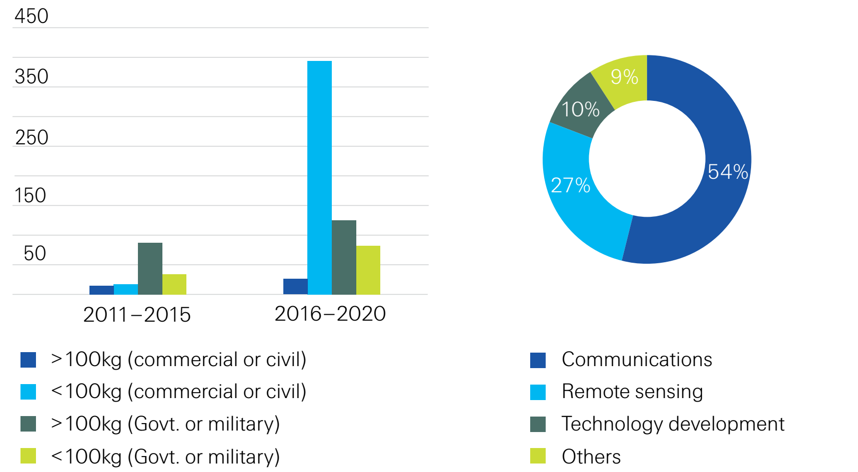


Source: Union of Concerned Scientists, Space Capital, Swiss Re Institute
Note: LHS denotes left hand side index, vice versa for RHS

...supported by modular assembly and improvements in solar power technology.

The availability of commercial off-the-shelf components is lowering ground-up development costs and standardising satellite build. This is in contrast to the traditional approach of making customised mission-specific satellites. As a result, the number of smaller in-orbit satellites (weighing less than 100 kg) has increased notably since 2017 (see Figure 3, (LHS)). Most smaller satellites rely on solar power, and recent developments in solar panel cell technology have enabled smaller satellites to operate with optimal power supply in space.[1] This has partly addressed the issue of revisit time, with commercial vendors able to launch a greater number of smaller and cheaper satellites in a single mission. However, more satellites in the orbit increase the space waste and the risk of satellites colliding with each other.

Figure 3
Active satellites by launch year and size (LHS); active smallsats by area of application (in 2020 (RHS))

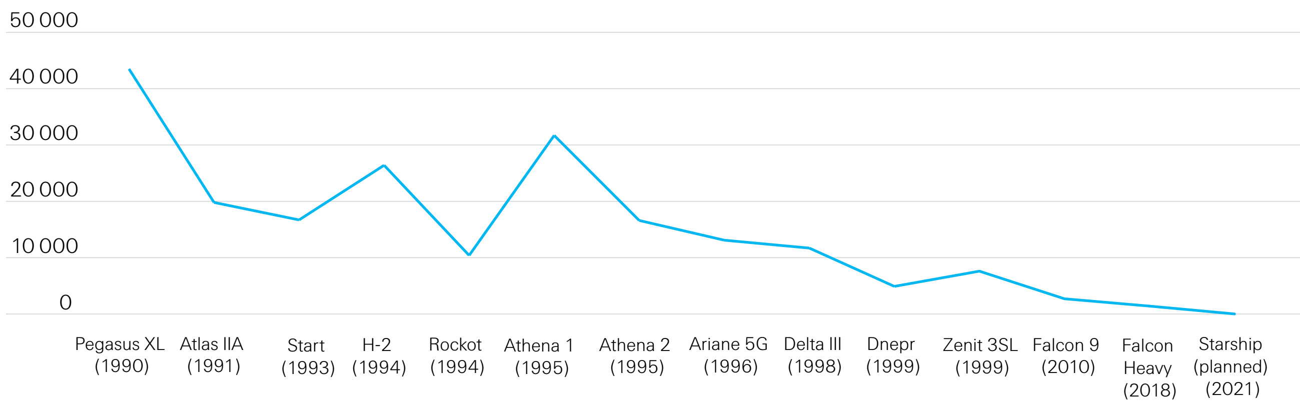


Source: Swiss Re Institute, Union of Concerned Scientists

Satellite launch costs have fallen with the availability of private-launch services.

Launch costs for low-earth orbit (LEO) satellites have fallen substantially (see Figure 4). Sector structural changes started in 2011, when NASA ended its space shuttle program to focus on earth science and deep-space exploration. This resulted in NASA awarding more contracts with research funding to private operators for the development of low-cost launch service capabilities, mostly for LEO deployment. Commercial launchers saved initial R&D costs by using readily-available rocket missile design. They also took on in-house end-to-end development of launch vehicles, which has proved more efficient than previous sub-contracting arrangements.[2]

Figure 4
Payload launch costs per kilogram for LEO at constant US dollars of 2018



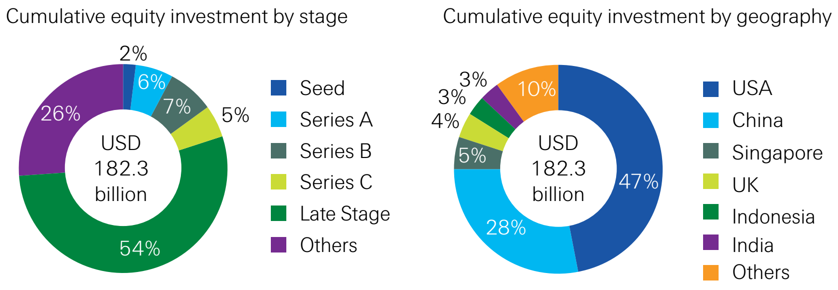
Source: Compiled by NASA and Swiss Re Institute

1 Satellite makers have now started including multi-junction solar panel cells in smaller satellites. This has multiple layers of light absorbing semi-conductors, which can use wider spectrum of solar radiation to make power. See section on power in *State-of-the-Art Small Spacecraft Technology*, NASA, 2020.
2 *The Recent Large Reduction in Space Launch Cost*, NASA, 2018.

Annual space tech investments have increased 13 times since 2012.

Greater accessibility to space has expanded the customer base for remote sensing and attracted more equity investment. Even with the effects of COVID-19 pandemic, in 2020 there was 28% year-on-year growth in funding to geospatial companies, taking total investment to around USD 28 billion; the US and China lead. Almost 70% of the funding in spacetech comes from venture capital firms.[3] There is growing interest from the public sector too, especially in launch services. More than half of cumulative equity investment since 2012 is classified as late-stage funding, underpinning market readiness for space tech solutions (see Figure 5).

Figure 5
Cumulative spacetech equity investments by stage and geography (2012–2020)

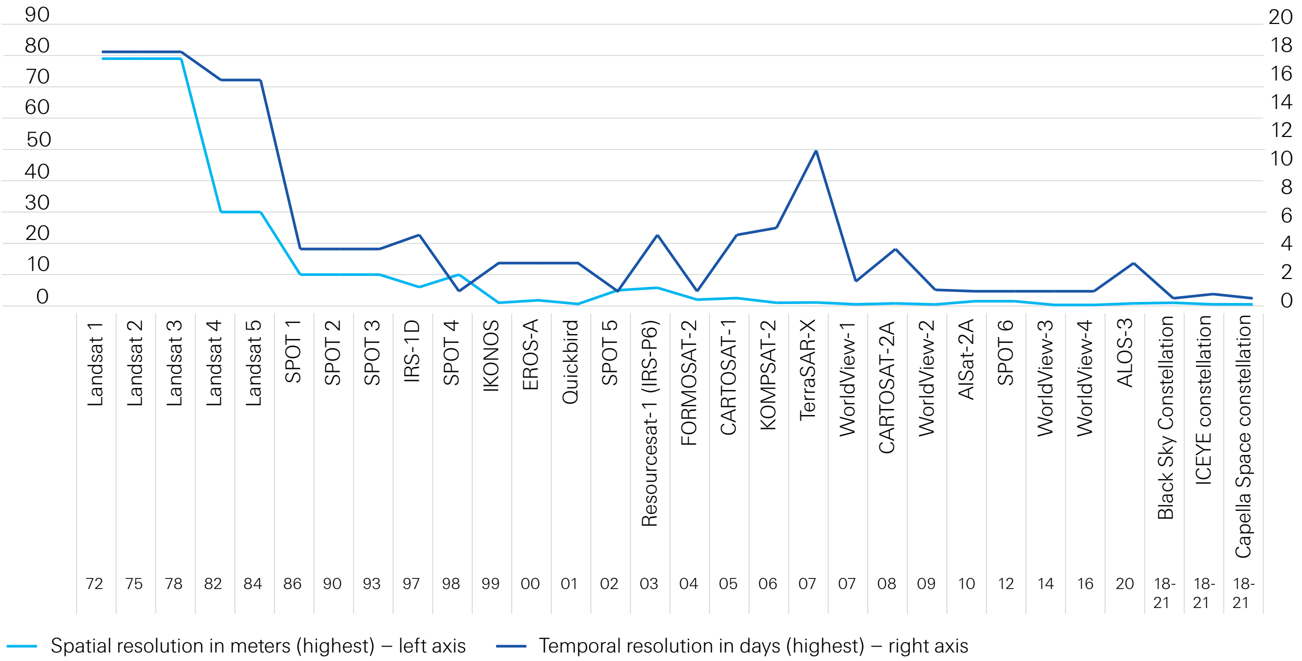


Source: Space Capital data as on 1Q2021

Advances in spatial and temporal resolution are yielding superior data collection capabilities.

Today, much-increased spatial and temporal resolutions are leading to additional and superior geospatial data collection methods. In the 1990s, a single pixel of a typical image represented about 20 square metres of land area. By 2000, a pixel represented around 10 meters. Today a resolution of 0.3 meters is possible from Digital Globe's WorldView-3 (see Figure 6). With improvements in spatial resolution, the focus is now on enhancing temporal resolution. Companies like ICEYE and Capella Space now work on synthetic aperture radar (SAR) small satellites to reduce revisit time and capture scenes more frequently. Improvements in resolution and ground equipment will enable intra-day insights.

Figure 6
Improvement in spatial and temporal resolutions over time (1972–2021)



Note: Spatial resolution depicted in the chart is highest across multiple sensors in a single satellite; temporal resolution is highest from either a single or a constellation of satellites. This chart is constructed from publicly available information and current information may differ from this chart due to rapid developments in satellite resolutions.
Source: University of Twente, European Space Agency, Swiss Re Institute

[3] Start-Up Space, Bryce Tech, 2020

Secure access to sensor and other complimentary data can foster new business models.

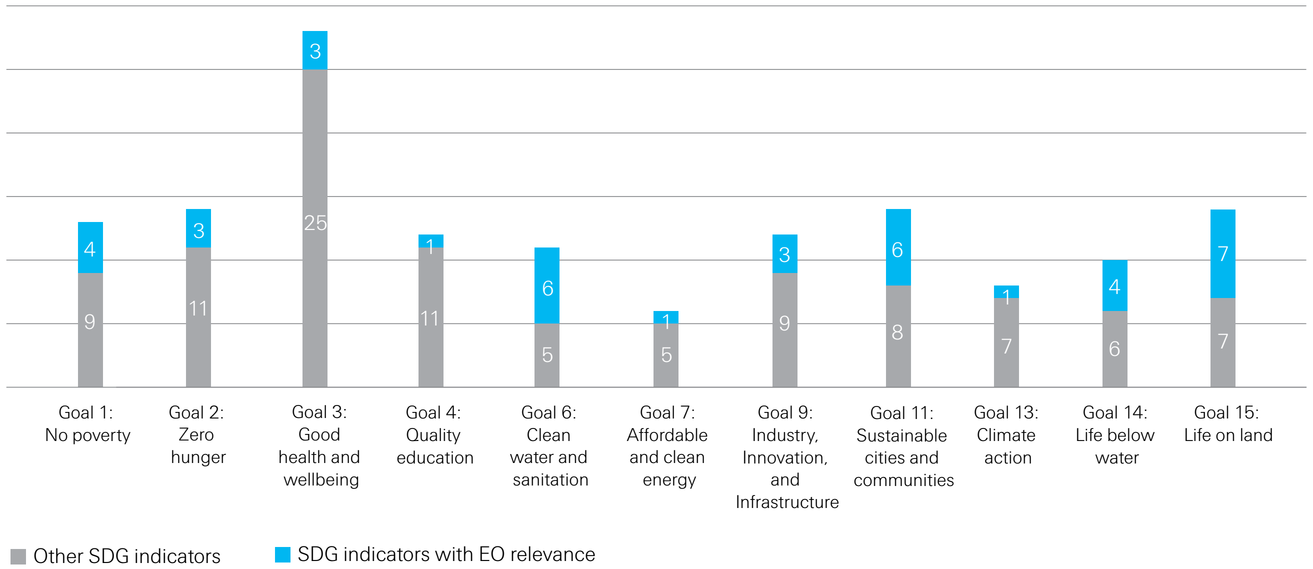
Over time, innovations will lead to a confluence of geospatial offerings delivered through new data-driven business models. Such solutions will be generic products fit for application across industries, later customised by adding business-specific data and context, including in insurance. Remote sensing vendors can layer near real-time geophysical insights with behavioural, situational and contextual patterns to enable autonomous visual intelligence. The advance of such capabilities will also progress global efforts to ensure a sustainable world for future generations. Governments and international agencies can also use the insights to monitor economic and planetary sustainability.

Measuring and advancing sustainability via remote sensing

Remote sensing can play a key role in building sustainable society.

There is growing recognition of remote-sensing-enabled EO as a complementary data source to progress the UN's Sustainable Development Goals (SDG).[4] The UN monitors progress for development goals by collecting socio-economic and environmental data under 17 SDGs broken down to 169 targets and 231 indicators. UN member states report most of this data in national statistics, but it often comes with a time lag or is patchy (eg, data on mountain biodiversity). Remote sensing can address many of these shortcomings (see Figure 7).

Figure 7
Collection of UN SDG indicators with earth observation relevance



Source: United Nations, European Space Agency, Swiss Re Institute

Remote sensing combined with in-situ data sources and national statistics can enable better tracking of SDGs.

High-resolution EO data can quickly and frequently reveal on-ground changes and support optimum allocation of resources. EO data for night light, vegetation cover, habitation patterns and hydrometeorology can be merged with ground surveys and other Big Data to create synthetic maps providing granular insights on different indicators. Swiss Re Institute analysis of UN SDGs and data from the European Space Agency suggests that at least 17% of the 231 SDG indicators can immediately benefit either directly or indirectly by using EO data. Many of these are also relevant for insurability and areas of risk modelling (see Table 1).

[4] SDGs promote economic and human development with the protection of environment. See *Transforming our World: The 2030 Agenda for Sustainable Development*, United Nations, 2015

Table 1
Examples of SDGs, with relevance of earth observation and insurance elements

UN Sustainable Development Goals (SDGs)	SDG Indicators	Relevant insurance line of business	Relevant remote sensing elements for insurance and SDG indicators			
			Maturity of EO technology	Availability of technical capacity	Availability of global EO data	Spatial scalability
Goal 1: No poverty	1.1.1 Proportion of population living below poverty line by geographic location (urban/rural).	Multiline	Medium	Low	Medium	Medium
	1.5.2 Direct economic loss attributed to disasters in relation to global GDP.	Property & Casualty	High	Medium	High	High
Goal 2: Zero hunger	2.4.1 Proportion of area under productive and sustainable agriculture.	Property & Casualty	Medium	Low	High	Low
Goal 3: Good health and well-being	3.3.3 Malaria incidence per 1 000.	Life & Health	High	Low	High	High
	3.9.1 Mortality rate attributed to household and ambient air pollution.	Life & Health	High	Low	High	High
Goal 9: Industry, Innovation, Infrastructure	9.4.1 CO2 emission per unit of value added.	Multiline	Medium	Low	High	Low
Goal 11: Sustainable cities	11.5.2 Economic loss, damage to critical infrastructure, disruptions to basic services attributed to disasters.	Property & Casualty	Medium	Low	High	High
Goal 13: Climate action	13.1.1 Number of deaths, missing and directly affected attributed to disasters per 100 000 population.	Life & Health	High	Low	Medium	High
Goal 15: Life on land	15.1.1 Forest area as a proportion of total land area.	Multiline	High	High	High	High
	15.4.2 Mountain Green Cover Index.	Multiline	Medium	Low	High	High

High Medium Low

Source: ESA Compendium of Earth Observation contributions to the SDG Targets and Indicators, Swiss Re Institute

The availability of technical capacity is the biggest hurdle in widespread adoption of EO for SDG tracking.

The technical capacity to meaningfully apply EO data to measure progress on SDGs varies significantly by country. Lack of processing infrastructure, talent and poor inter-operability across disparate data frameworks remain the biggest hurdles for integrating EO with national statistics. Institutional structures within and beyond the UN seek to address these challenges to improve regional and national decision support systems. Insurers must take their seat at the table on such discussions.[5]

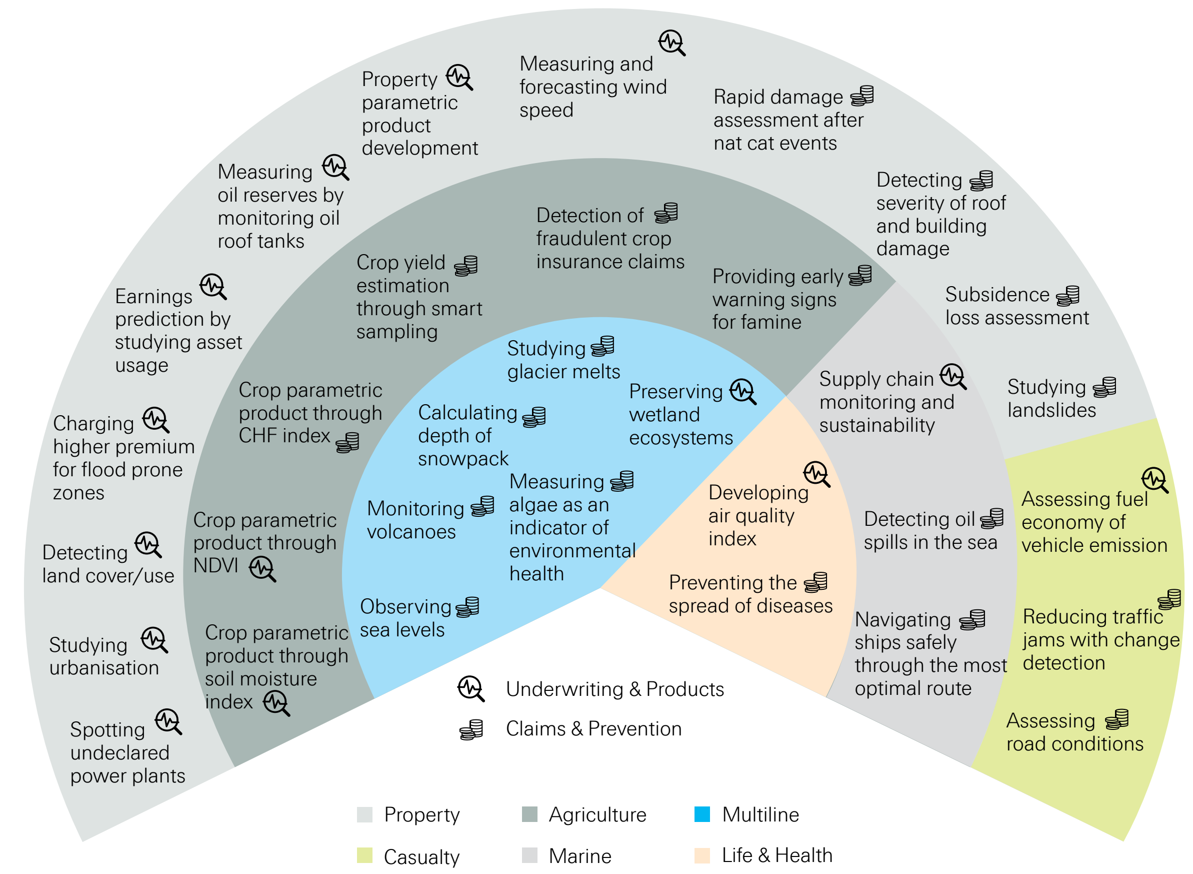
Remote sensing and insurance

There is growing awareness in insurance of the potential that remote sensing technology offers.

The insurance industry is becoming increasingly aware of the potential of geospatial data in risk modelling. Geospatial Insurance Consortium (GIC) is an example where insurers are coming together to develop geospatial intelligence customised for the industry. Insurers can leverage insights derived from remote sensing across their value chain, to enhance risk modelling and financial intelligence across many lines of business (see Figure 8).

[5] The Group on Earth Observations (GEO) is a global initiative to promote open sharing of EO data and infrastructure to build a sustainable world. EO4SDG is one of the GEO initiatives to utilise earth observation data to enable SDG achievement.

Figure 8
Remote sensing applications for sustainable insurance



Source: Swiss Re Institute

Remote sensing can enhance risk modelling and overall insurance sector functions.

Integration of remote sensing data in their value chain can help insurers better price and monitor their own portfolio of insurance risks, and influence the design, usage and maintenance of clients' assets and facilities. In addition, remote sensing can enable prevention and mitigation measures eg, early warning signals from SAR satellites for wildfire or landslide. Commercial data and satellite vendors have started offering customised data offerings to insurers. Such unique and large remote sensing data enriched with insights from asset behaviour, connected objects and historical losses can enable superior and more accurate risk modelling. The data can be used for pricing and real-time adjustment of coverage based on changing risk profiles. Insurers could also leverage the data insights to detect fraud and offer enhanced risk intelligence, prediction and prevention services.

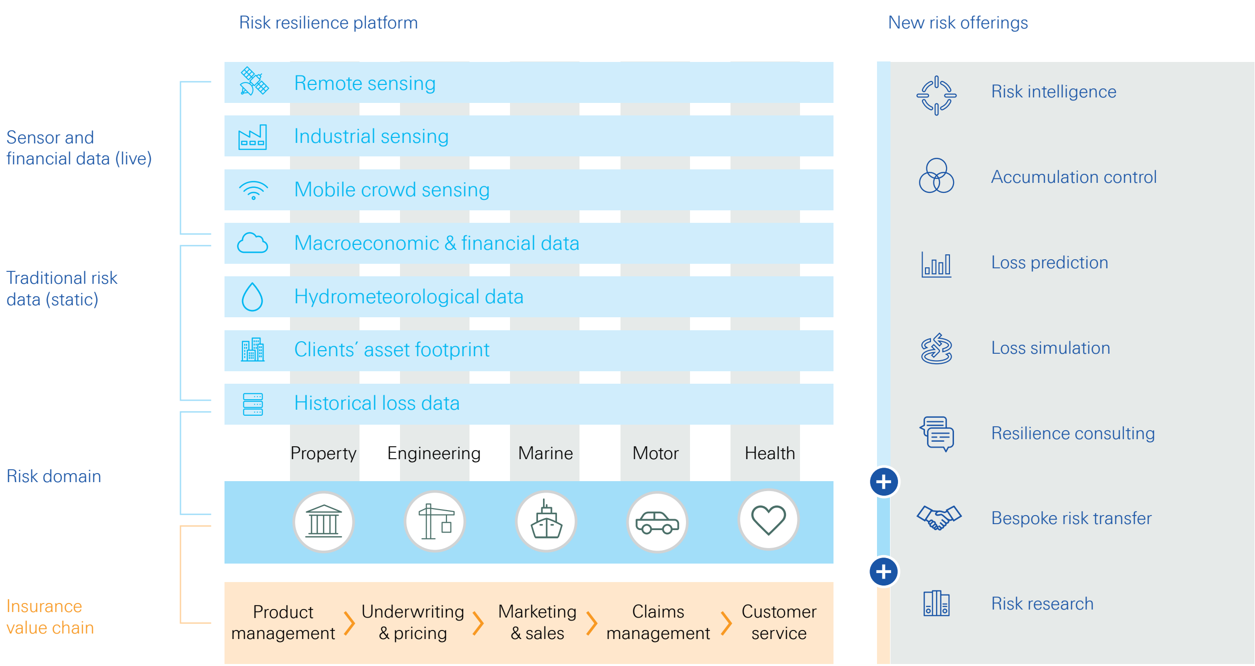
Commercial risks can benefit from remote-sensing enabled insights.

Insurers have already started using third-party data to auto-fill proposal forms and develop risk scores for SMEs and mid-corporate risks.[6] There is still some way to go in digitising information critical for underwriting large corporate risks. This segment will benefit most if visual intelligence from remote sensing can be fused with live data from industrial control and monitoring systems. The data could be built into platforms whereby clients are able to track inherent operations risks and predict frequency and severity of losses by asset (building, machinery, stock) and location (see Figure 9). Integration of real-time data on commodity prices, interest rates,

[6] *sigma* 1/2020 - Data-driven insurance: ready for the next frontier?, Swiss Re Institute

inflation and wages could further enhance platform value by enabling the running of simulated estimates of losses and time needed to restore operations.

Figure 9
Stylised representation of a risk resilience platform



Source: Swiss Re Institute

Insurers may need to invest in new data businesses and initiatives.

Such business models will require secure access to data including insights from connected objects, platform providers, behavioural insights from consumers and environmental data. The seven categories in Figure 9 are examples of data that will be available to insurers. Some of these are newer (eg, consumer behavioural data), and others more traditional data sources (eg, from claims and preventive services). Different stakeholders will seek control over data-driven businesses and insurers will need to keep up with developments in data aggregation to retain their relevance. For instance, if data brokers become omnipresent, over time it could happen that insurers face a risk of being relegated to the status of information suppliers.

Demand drivers of remote sensing in insurance

Leveraging remote sensing in insurance

Claims assessment and parametric product development are the main use cases for remote sensing in insurance.

Remote sensing can expand the bounds of insurability and make households and businesses more resilient, thus contributing to a more sustainable future. Examples of insurance processes that can benefit already are granular indices for parametric products, rapid claims assessment and early warning alerts for customers. These outcomes either directly or indirectly can promote a number of UN SDGs and enable the insurance industry to play its part in fostering sustainability and resilience for society at large (see Table 2).

Table 2
Primary use cases of remote sensing in insurance

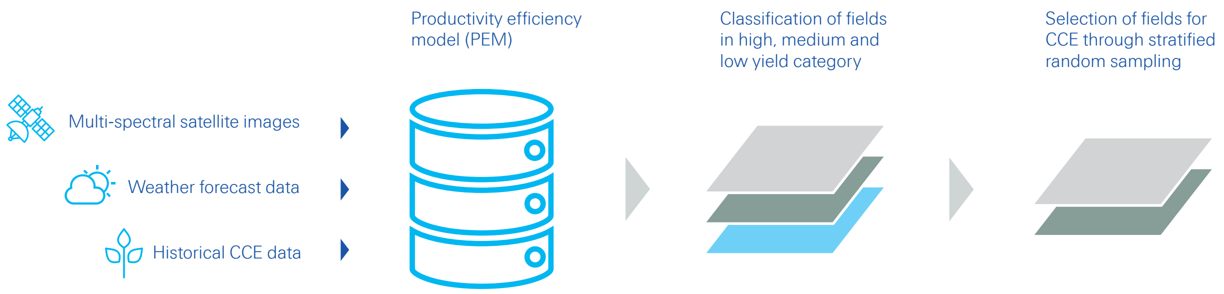
Value chain	Line of business	Use case	Remote sensing technology	Benefits	Challenges	Future applications	Link to the UN SDGs
Claims assessment	Agriculture	Crop yield estimation to assess and settle claims.	Smart sampling enabled by both passive and active (SAR) remote sensing.	Less manpower required to estimate yields. Reliable sampling and cost saving.	Establishing correlation between remote sensing vs historical yield data.	Risk assessment, early warning for preventable crop losses.	2, 12
Claims assessment	Property	Rapid damage assessment after large scale flood events.	Flood maps enabled by both passive and active (SAR) remote sensing.	Faster decisions on claim admissibility and settlement. Better reserving and lower moral hazard.	Measuring peak flood height and time for which water stands still.	Loss prediction and risk monitoring. Deployment and planning of claims adjusters to detect affected policy owners.	11, 13
Underwriting and claims assessment	Property	Detecting severity of roof and building structure damage.	Passive (aerial) imagery analysed with semantic segmentation.	Faster underwriting. Better reserving and lower moral hazard.	Aerial imagery can be costly and difficult to acquire at short notice.	Property loss prediction and risk monitoring.	11, 13
Claims assessment	Property	Subsidence loss assessment and prediction for sinking structures.	Active (Differential Interferometric Synthetic Aperture Radar or D-InSAR) images analysed over long time.	Faster decision on claim admissibility and settlement.	Hard to achieve higher temporal resolution across different generation of satellites.	Landslide and subsidence risk assessment and monitoring.	11, 13, 15
Product development	Agriculture	Crop parametric product for drought risks based on soil moisture index.	Passive (microwave) images to measure soil moisture levels.	Automated underwriting and payout. More comprehensive than Normalized Difference Vegetation Index (NDVI) and rainfall index.	More customisation required for adjusting the index to crop type and sowing stage.	Similar products for pasture or yield based crop insurance.	2, 12
Product development	Property	Property (Flood) parametric product based on excess rainfall index.	Passive remote sensing images combined with data from ground-based weather stations.	Affordable product with automated underwriting and payout. Longer time series of weather data.	High basis risk. Not suitable for single location risk and retail customers.	New wind parametric products using data from satellites such as Aeolus.	11, 13

Note: Passive sensors observe objects illuminated by sunlight or self-illuminated objects. Active sensors emit energy (radio, sound & light waves) to illuminate objects and they can operate in night and all-weather conditions.
Source: Swiss Re Institute

Remote sensing-assisted smart sampling can improve the quality of yield data…

Crop yield estimation to assess and settle claims
Insurers currently collect yield data via crop-cutting experiments (CCE) in a defined area chosen via random sampling. CCEs are time and resource intensive, prone to moral hazard and basis risk. These drawbacks can be mitigated by smarter sampling, such as by combining historical CCE data with satellite images and weather data to create productivity efficiency models (see Figure 10).[7] These models generate crop yield proxies that can be used to classify fields into various yield segments (high to low). Subsequently, these fields can operate as better or smarter samples for the larger area. CCE data in smart sampling is more representative of the actual crop situation, and this helps reduce basis risk.[8]

Figure 10
Stylised representation of smart sampling process



Source: Swiss Re Institute

…by assisting and complement existing yield estimation processes.

Large developing countries could experiment with remote sensing in the context of crop insurance programmes to promote productive and sustainable agriculture under SDG indicator 2.4.1. Although historical yield data sets may be inaccurate and difficult to correlate strongly with independent data sets from remote sensing, these problems will ease as yield data sets improve. Better yield estimates can also help in efficient food storage and distribution, thus preventing food loss (SDG indicator 12.3.1). A remote-sensing enabled index will still need other datasets (eg, rainfall, wind, precipitation) to model other peculiarities of a crop. As such, greater use of hybrid modelling approaches which integrate multiple datasets will likely be forthcoming, since no single model can give accurate results.

Remote sensing-enabled flood detection can provide access to timely insights for claims development.

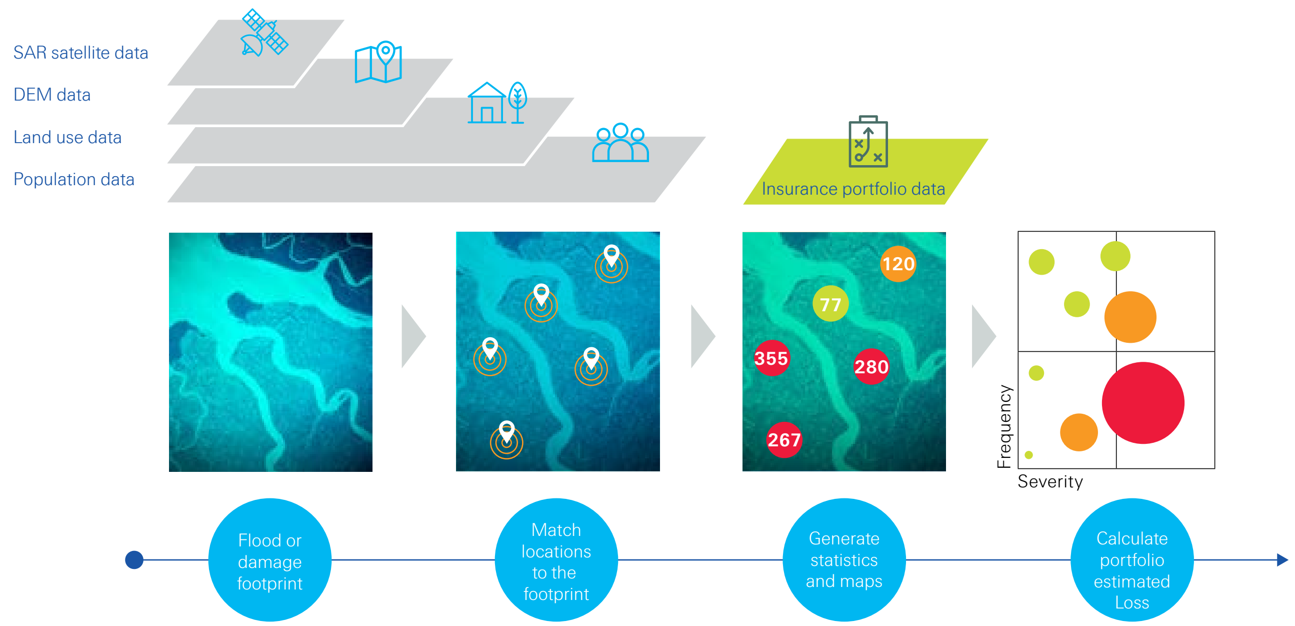
Rapid damage assessment after large-scale flood events
Flood events restrict mobility and damage transport infrastructure, which can make it difficult for surveyors to get a quick and accurate picture of losses. Satellite images can be used to detect floods and measure the extent of losses, more so if data on water depth, flood area and event duration are combined. This includes both inland (pluvial and fluvial) floods and coastal (storm surge) floods. Early warnings or quicker claims settlement can foster customer trust and loyalty, not least as floods can happen very quickly. Street level insights on inundation can be used as input for faster claims settlement and may also lead to better vulnerability curves for risk models. Also, more accurate and objective loss assessments can enhance reserving estimates and enable SDG indicator 11.5.2 related to quantifying economic loss to critical infrastructure and services.

7 A pilot study by Government of India suggests a possibility of 30-70% reduction of CCEs (based on the crop and geographical region) by using remote sensing data. See *Use of Modern Technology for Assessing Damage to Crops*, Ministry of Agriculture & Farmers Welfare, Government of India, 22 November 2019.
8 Shibendu S. Ray, "How India is using space technology to 'smart sample' crops", *natureasia.com*, 3 March 2021.

SAR-satellite data combined with digital elevation models can improve flood risk modelling.

High-resolution images from SAR satellites can differentiate water from the land by measuring water reflection. Digital elevation models (DEM), where available, can be used to measure flood depth, and the resultant output enriched with geo-referenced portfolio data to generate individual risk level damage estimates and vulnerability curves for flood modelling (see Figure 11). DEMs are crucial for measuring flood depth. Their quality has evolved with advances in data sourcing and processing methods. Early methods were based on ground surveys and topographic map conversions. Newer methods leverage passive remote sensing, and more recently active sensing with Light Detection and Ranging (LiDAR).

Figure 11
Stylised representation of rapid damage assessment for flood



Source: Swiss Re Institute

Remote sensing offers high-level visual overview, but there are regional variations.

Insurers will have to account for regional variation in data quality. Regions with many detached and individual houses are more suited for loss assessment using remote sensing. In urban areas, interference of high-rise buildings may create problems in acquiring images of inundation, although techniques are being developed to address these challenges. The cost-benefit trade-off can also depend on the size of economic losses. For example, in some emerging markets the authorities provide physical reports on flood situations for assigned areas, every few hours via online messaging tools. Hence in some situations, where there are large numbers of people on the ground in an assigned area, remote sensing may offer fewer incremental benefits than, for instance, could be derived in areas of less population density.

Remote sensing can help assess property damage after a large event.

Detecting severity of building damage from hurricanes
Aerial imagery can be used to provide individual property-level damage estimates, which is timely when insurers are processing high claims volumes and ground level loss information is not available. Insurers may overlay their portfolio data with aerial imagery and weather forecasts to assign a loss probability and amount for each insured property even before a hurricane hits (see Figure 12). Machine learning can help identify objects in an image, but this requires extensive training data and high resolution (5cm per pixel) aerial images. Satellite images may not be granular enough for individual property level loss assessment. Wider availability of such analyses can help policy makers develop and implement SDG indicator 13.1.2 and

13.1.3, which relate to national disaster reduction strategies at the local and national levels. The current limitation however is that damage within the building is difficult to assess eg, from water that has entered into the building via rain or sewer.

Figure 12
Stylised representation of detecting building damage after hurricanes

Source: Swiss Re Institute

Subsidence losses are on the rise and claims admissibility is difficult to prove.

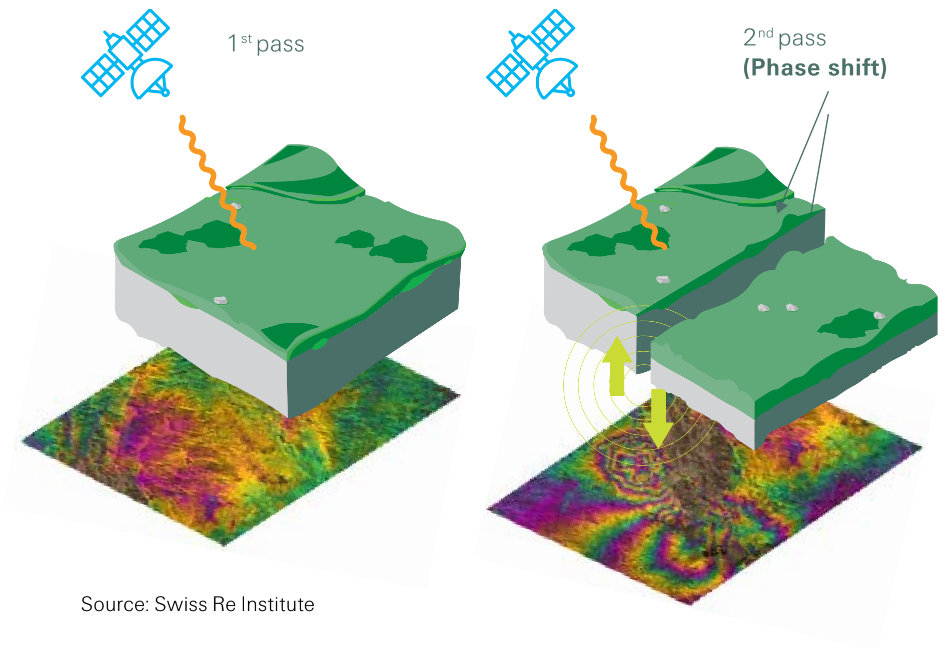
Subsidence loss assessment and prediction
Remote sensing, especially D-InSAR satellite data can be used to calculate soil movement for subsidence risk and claims assessment in property insurance. Subsidence (downward movement) or heave (upward) usually results from the ground beneath a property collapsing or gradually moving, mostly due to hot, dry weather. Subsidence is a problem in some European countries, especially France where inflation corrected-insured losses from subsidence since 2016 have exceeded EUR 550 million each year. The average annual loss has increased to EUR 810 million from EUR 310 million in 2000–2015.[9] Assessing and settling subsidence claims is challenging since it can take several years for the losses to appear, and the admissibility of claim cannot be proved by straight inspection which results in higher litigation.

Differential InSAR satellites help can calculate soil movement.

D-InSAR satellites can capture images of the same area at different times and compute the difference in "return of signal" from the ground back to the antennae, also known as "phase difference" or interferogram (see Figure 13). D-InSAR satellites are being used to calculate the millimetre level ground displacement based on spatial and temporal patterns of the bending, range and acceleration of soil movement. However, phase difference can occur for reasons other than subsidence. Therefore, the data needs to be cleaned and processed to arrive at a conclusion for or against subsidence. This application does not require very high revisit frequency: one image a month can be sufficient, although extended time series of historical data are needed to observe and analyse ground deformations.

[9] *Les catastrophes naturelles en France, Bilan 1982–2019*, Caisse Centrale de Réassurance, 2020.

Figure 13
Application of D-InSAR satellite in assessing subsidence



Source: Swiss Re Institute

Soil moisture can also be used as a proxy to assess subsidence.

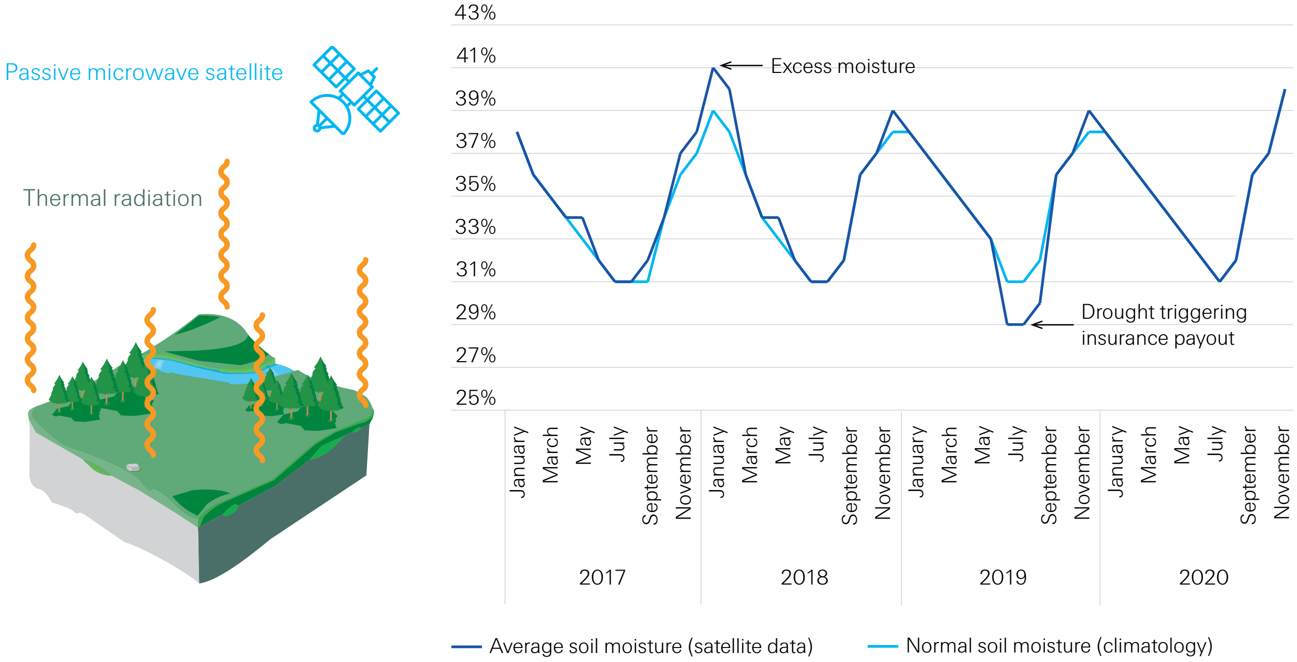
Soil moisture data obtained from passive microwaves can complement data from D-InSAR satellites, to measure subsidence, as fine clay rich soils have a tendency to swell or shrink based on water content. For example, subsidence due to poor soil moisture has been a problem in the UK and France due to the nature of soil and recent dry years. This data can also be used for claims assessment. Swiss Re has looked into expected losses from subsidence, using soil moisture data in France, and developed a model that provides an order of magnitude in terms of how much the subsidence losses are likely to be. In France, municipalities get pay-outs when a catastrophe is declared, and there was a strong correlation between the predicted subsidence and where emergencies had been declared. Satellite-enabled measurement of soil moisture and vegetation can also help measure loss of biodiversity in mountains (SDG 15.4.2) and in doing so, improve assessment of landslide risk in such regions.

Remote sensing can support the development of parametric insurance for drought related crop losses.

Parametric covers for crop drought-related losses using soil moisture index
Passive microwave (optical) satellites with a 100m X 100m resolution can help measure soil moisture at field level. This data can be used to develop a soil moisture index to indemnify for drought related crop losses, since data providers provide daily access to soil moisture data for different crops and their growth phases.[10] Passive microwave imaging offers the advantage of an unhindered view despite clouds. It can measure soil moisture per cubic meter of soil on a daily basis and the data is backward averaged to reduce volatility of daily moisture content. The resulting datasets are then compared with normal soil moisture conditions for that area. The extent and duration of variation from normal conditions over the years reflects drought conditions or soil moisture shortfall (see Figure 14).

[10] Van der Sat has a patented spatial downscaling method which can convert coarse resolution images (25kmx25km) in to 100mx100m high resolution images. See "Detailed soil moisture data", *vandersat.com*

Figure 14
Stylised representation of soil moisture variation assessment



Note: The graphic and its values are for illustrative purposes only.
Source: Swiss Re Institute

Index-based insurance addresses problems of cost and access to affected areas.

Property (flood) parametric insurance based on excess rainfall index
Insurers are also implementing rainfall index-based flood insurance, where pay-outs are triggered if rainfall exceeds a pre-determined level. Satellite-based rainfall indices are based on the combination of data from ground-based weather stations and grid-based mapping of targeted municipality, city or district from satellite images. The mapping divides targeted areas into homogenous units based on pixel data per grid. The payout is triggered if cumulative rainfall exceeds a certain threshold within a pre-determined time window. These products are relatively quick to implement, if data is available, but are also subject to basis risk. Run-off modelling uncertainties can add to basis risk. Beyond flood, satellites could also enable new parametric wind products, for example, with the latest satellite Aeolus, it is possible to get better wind fields, even without wind measurement stations on earth.

Enterprise-scale deployment in insurance

Initial use-cases have yielded promising results, but wider application in the insurance sector will take time.

Remote sensing technology has seen more commercialisation due to increasing affordability of high-resolution images, and the development of various machine learning approaches. However, the complexity of use cases requires integration of several in-situ data sources with satellite images, and this presents technical challenges. While many data vendors focus on extraction and distribution of data, few concentrate on data curation and refinement. No single firm or marketplace currently provides all these sources of data. Securing access to this data is a strategic issue, taking insurers beyond their existing value chain.

Scalability of data driven insurance solutions depends on the emergence of rich data ecosystems.

We expect that this will give rise to specialised aggregators focused on integration and curation. The more integrated and refined the data, the wider the service offering to a customer. This emerging data ecosystem has many implications for the insurance industry, in particular the need for modular products, better distribution and underwriting. Scalability of data-driven insurance solutions requires customisation even within the same use-case category. This necessitates a long-running pipeline of projects and appropriate data infrastructure, talent, legal safeguards and organisational buy-in.

Management factors for an insurance data ecosystem

Regulatory uncertainty around data privacy could limit scalability of insurance solutions.

Privacy and regulatory concerns: Concerns over data privacy and potential reputation risk may increase with the advent of high-resolution commercial remote sensing, and improving data enrichment and dissemination systems. However, international regulations around the use of data obtained via remote sensing technologies are still in early stages of development and may vary by the market. This can add uncertainty in terms of scalability of insurance solutions across markets:

- From the perspective of national security, countries can place safeguards on the production of high-resolution imagery within their boundaries, but cannot regulate images produced by other jurisdictions. Guidelines recommend that remote sensing by one country should not be conducted in a manner detrimental to the legitimate rights of another country.[11] However, this is not legally binding and countries do not have veto power to prevent themselves from being monitored.[12] This could have insurance implications, such as if there are restrictions around usage of locally produced images of assets underwritten by foreign insurers.

- Satellite resolutions are not yet sufficiently refined to spy on people or track their mobility at scale. But placing this information in the context of geographical locations may make insureds identifiable to some extent. In Europe, the General Data Protection Regulation (GDPR) includes provisions which can make a remote sensing company subject to privacy and data protection laws. However, to date there is no global legislation on regulating personal data obtained through remote sensing.

- Cloud platforms are used by remote sensing companies to make data more accessible in a cost-efficient manner. However, it is difficult for nation states to determine the origin of such data and control or monitor access. The issues become more complex when satellite images are enriched with complementary data sources. To date there is no international legal framework on cloud storage and computing. However, more restrictive regulations in future could undermine access to remote sensing business-critical data, including for insurers.

[11] "Principles Relating to Remote Sensing of the Earth from Outer Space", in *Resolution adopted by the General Assembly, 41/65*. United Nations Office for Outer Space Affairs, 1986.
[12] *Satellites, Remote Sensing and Big Data Legal Implications for Measuring Emissions*, Centre for International Governance Innovation, 2017.

Significant customisation efforts are needed to make remote sensing solutions applicable across markets

Solving for geographical differences: Remote sensing adoption varies significantly by line of business and geography. For example, variations in agroclimatic zones, rainfall patterns and heterogenous in-situ data sources may render existing applications irrelevant in specific markets. From the insurance perspective, different building structures and habitation patterns can entail substantial variation in rapid damage assessment of residential property after a flood. Substantial effort is required to even make successful use cases compatible with local requirements.

In-house development of remote sensing capabilities requires heavy investment.

Build versus buy: Setting-up remote sensing infrastructure is complex given a varying range of resolutions, computational algorithms and analytics platforms. Also, high-quality images from commercial vendors can be expensive relative to those available from federal open-source databases. This requires substantial investment and commitment to build in-house remote sensing capabilities. Insurers struggling with thin margins may not have the spending capacity to support remote sensing activities within the firm. In addition to acquiring images, successful implementation enterprise-wide also involves developing the right talent for processing, analysing and taking the finished product to market. Partner selection will be a challenge given the domain expertise needed for providing specific insights; different vendors will focus on specific verticals.

Technical factors

Fusion techniques are used to address gaps in satellite images acquired from different sensors.

Image fusion from multiple sensors of varying quality: Different satellites provide information on distinctive risk features of an insured object. For example, for the purposes of property insurance, an optical satellite can provide structural information about a building, LiDAR provides the elevation data, and multi/hyperspectral sensors provide material content. Also, a satellite rarely offers high spatial, temporal and spectral resolution all at the same time. Image fusion from multiple sensors with different wavelengths can help fill such data gaps for the purpose of insurance risk or claims assessment, but this does require complex fusion methods and expertise. These are classified either as image dimensions (ie, spatio-spectral or spatio-temporal fusion[13]) or at different processing levels (pixel level fusion, feature level fusion or decision level fusion.)

SAR can be used to fill data gaps that optical images do not cover.

Accessing machine learning and data curation expertise is critical: Machine learning on SAR data is still considered challenging due to lack of labelled data available to insurers. Machine learning approaches in remote sensing must leverage both passive optical and active radar imaging modalities. This multi-modal machine learning can utilise the complementary information from multiple sensors to improve the accuracy of models.[14] The aim for insurers is to combine data from satellites with other sources to gain a comprehensive understanding of damage to an insured asset. Weather data, river gauges, elevation data and optical imagery all have their part to play in producing final insured loss estimates.

Heterogeneity of use cases requires enrichment of remote sensing data with diverse data sources.

Processing and curating a variety of insurance relevant data sources: Several players in and beyond the remote sensing industry (tech & data providers) are offering services to insurers, with the promise of greater data enrichment in enabling insurance processes. However, the breadth and diversity of data sources now available raises several questions with regard to cost, coverage, predictive power, regulation and challenges of leveraging these data sources across different insurance risk pools and geographies (see Table 3).

[13] H. Albanwan, R. Qin, "Spatiotemporal Fusion in Remote Sensing", *intechopen.com*, 4 November 2020.
[14] C. Rambour, N. Audebert, E. Koeniguer, B. Le Saux, M. Crucianu, M. Datcu, "Flood detection in time series of optical and SAR images", *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Copernicus Publications, 2020.

Table 3
Features of various data sources

Data sources	Latency/ revisit time	Geographical coverage	Temporal resolution	Spatial resolution	Availability	Cost	Scalability	Predictive power
Satellites	Near real-time	Global	High	High	High	Chargeable	High	High
River gauges	Real-time	North America and western Europe	High	NA	High	Mostly Free	Low	High
National meteorolo-gical sites	Real-time	North America and western Europe	High	High	High	Chargeable	Medium	High
Unmanned aerial vehicles (UAVs)	Not real-time	North America and western Europe	Low	Low	Medium	Chargeable	Low	Medium
Airplanes	Not real-time	North America and western Europe	Medium	High	Medium	Chargeable	Medium	Medium
Mobile and social media data	Near real-time	Fragmented	NA	NA	Medium	Chargeable	Low	Low
IoT sensors in buildings and machines	Real/Near real-time	Fragmented	Medium	NA	Medium	Chargeable	Medium	Medium

Source: Swiss Re Institute

River gauge data is complementary, but the availability is fragmented.

Case study: optimal use of fragmented river gauge data for flood forecasts: Insurers can use remote sensing and hydrological data in complementary ways. Satellites can provide river flow and floodplain visibility in areas with poor river gauge coverage, while real-time hydrological data can address the problem of satellite revisit time in case of peak floods.[15] River gauges measure stream flow discharge[16] through installed manual gauges and velocity sensors. Temporal resolution is quite high, with data going back to the late 1980s and usually free of cost. In North America and western Europe, countries have established practices of river gauging with decent coverage. Many developing countries, however, do not.

National meteorological sites data have regional variations, which impeded scalability.

Weather forecast variations at sub-national level: Weather data is a critical component of insurance risk models. This data is usually provided by government-run national meteorological sites with good temporal and spatial resolution.[17] In North America and western Europe, these sites provide APIs and entry points for industrial solutions. Some also provide alert services and live feeds. However, in larger developing countries, weather forecasts are in line at the national but vary greatly at the local level. These discrepancies emerge from a general lack of weather monitoring infrastructure, which means there are gaps in the data that are used for weather prediction models. Also, often weather models in such markets are imported and not necessarily adapted to local climate and environmental conditions. These variations can reduce insurers' ability to scale solutions across markets.

[15] Hydrological and meteorological data is used together for flood forecasting. Meteorological data provides the rain forecast while hydrological data helps in calculating the flood response on ground.
[16] Streamflow discharge is volume of water discharge in a river.
[17] National meteorological sites in developed markets have forecasts available from less than 24 hours, to short-range forecast up to three days and extended range for up to 30 days.

UAVs are mostly useful in localised application, but resolution is low.

Low resolution of UAVs due to turbulence: UAVs are easy to purchase, set-up and use, but there is a trade-off between coverage and payload capacity. Slower crafts are more stable and collect better imagery, but their application is site-specific. Faster craft carry limited number of sensors and utilise most of their energy for propulsion which means less energy for sensors. The resulting images can sometimes lack details and can be worse than free satellite images. The image resolution from UAVs in general is the lowest area per pixel - less consistent and granular. There are variations in availability and regulatory landscape, and adverse weather and climate conditions (eg, wildfire) also affect applicability.

Outlook

Insurers' willingness to invest in long-term data partnerships is crucial for success of such initiatives.

Rich geophysical insights can reduce paperwork around submissions, risk inspections and claims assessment. Situational and behavioural insights from crowd and industrial sensors can reduce moral hazard and improve fraud detection. In the future, insurers will operate in an environment where they will need continuous access to remote sensing and many other data sources to generate these insights. Success of these endeavours will depend on insurers' willingness to experiment and invest in new partnerships and data marketplaces to ensure continuous and secure access to customers and new business models.

Proprietary data driven insights can allow insurers to access new business models beyond insurance.

The potential is vast. Current fragmented views of complex risk can transform over time into dynamic portfolio monitoring capabilities. The impact of data and intra-day insights from drones, satellites and other sources can also extend beyond the insurance value chain, to monitoring and improving the resilience of the whole business ecosystem in which insurers operate. Industry boundaries will become blurred as firms in several sectors including insurers build digital platforms that can connect to different marketplaces, supply chain hubs and financial networks.

Conclusion

In the medium term, remote sensing will be relevant for mass insurance programs and parametric products.

Recent innovations in remote sensing technology have significant potential to streamline existing insurance processes and open new markets, as well as promote the UN's Sustainable Development Goals. Such solutions can build up societal resilience and help improve activities in the insurance value chain, including on-ground claims assessment, mitigate moral hazard and enable faster claim payments. In the medium term, enterprise-scale deployment of remote sensing will likely gain in areas such as rapid damage assessment and development of parametric products, before expanding into areas like underwriting processes.

Remote sensing can complement existing insurance value chain processes.

Governments and large private sector re/insurers have been the main adopters of remote sensing solutions, as part of mass insurance programs. They can afford the cost and at times subsidise such solutions for smaller insurers. Mass insurance programmes have time-tested procedures and operational infrastructure for claims assessment, and remote sensing solutions can complement and improve efficiencies. On the solutions front, remote sensing inputs can validate existing costing approaches and inform more reliable indices for parametric products.

Successful applications will require insurers and remote sensing vendors to be highly adaptive.

Remote sensing has been used for decades to build risk models at a global scale. These models leverage EO data for weather observation, population density, DEMs etc. The new development is that this data is now available with much higher resolution (time and space) at a lower price. This is the big change and allows to leverage those products efficiently in the insurance space. Wider adoption will primarily depend on selecting the right use cases and partnering for the long-term with vendors willing to customise and adapt their solutions. In the last few years, some vendors have been building insurance knowledge and have started to offer more context and value-added services, in addition to high-resolution images. Insurers also have their task cut out with building the right infrastructure and talent to integrate new solutions in the value chain.

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