A Novel Remote Sensing Technology for Frontier Exploration Using Biosensors and Scanning Laser (Lidar) Technology*

Heinrich W. Meurer[1]

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[1]GeoTec Exploration, Bruehl, Germany. (geotec@magicvillage.de)

Abstract

An airborne technology is proposed to detect in flight over wide areas with a high spatial resolution the presence of trace hydrocarbons and microseeps on the ground. It makes use of genetically engineered but environmentally safe soil bacteria, which function as sensitive and specific fluorescent biosensors for traces of light hydrocarbons (C1-C4) on the ground. Biosensors are spread using conventional crop duster planes equipped with precision flight management systems. Biosensors in contact with traces of light hydrocarbons react with the production of fluorescent proteins in their cell envelopes. These proteins - if excited with light of the correct wavelength - are capable to emit fluorescent light. As the fluorescent light is of a longer wavelength (stokes shift fluorescence) it is easily distinguishable from the excitation light. An airborne scanning Laser is used to excite, detect and georeference fluorescent light from biosensors. The sequence of excitation, detection and georeferencing is happening instantaneously and is done in a single pass of a search aircraft over wide areas of interest. Simultaneously a digital elevation model (DEM) of the surveyed area with a spatial resolution of 1 meter is produced. Any finds of fluorescent light from biosensors are recorded and integrated in the digital elevation model together with color-coded intensities for the detected fluorescent light. They are expected to be easily visually interpretable by geologists without further handling or manipulation of the data. Hot spots or extended areas with fluorescent light are proof of seeps of trace hydrocarbons indicating potentially commercial deposits of oil or gas. As an airborne technology, the possibility to search large areas of unexplored land for even the slightest signs of hydrocarbon microseepages exists. This makes it an ideal tool for “first time ever” frontier exploration. As there is no need to put a foot on the ground the technology is well suited to explore remote, rugged or dangerous environments. The concept of exploring for oil and gas using biosensors and an airborne scanning laser is based on unpublished results of an ongoing security research project in Germany dealing with the airborne detection of trace explosives and landmines.

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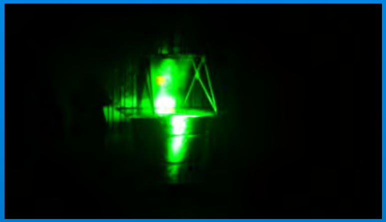
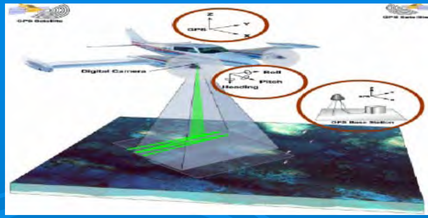
Frontiers of Unconventional Thinking: Saddle Up for the Ride

A Novel Remote Sensing Technology for Frontier Exploration Using Biosensors and Scanning Laser (Lidar) Technology

Heinrich W. Meurer
Geo Tec Exploration, Bruehl, Germany

Successful Oil Exploration is about finding new reserves as quickly as possible while minimizing risks and still observing sound economic principles.

How is it done in frontier exploration over wide areas ?

- We have satellite based hyperspectral sensors and Radar to search for colour clues on the land surface and generate digital elevation models to find on the surface print throughs from structures and faults down below.
- We have airborne gravimetry and magnetic surveys flown with fixed wing aircraft to get ideas on the extend and volume of sediments in a basin.
- We can install on an aircraft various artificial noses to sniff the air for traces of hydrocarbons originating from oil deposits (for example Shell´s Light Touch technology)
- We can fly in thunderstorms to record variations in the electrical field of the overflown area.

These are all remote sensing technologies

- To look for actual drilling prospects and to be able to spud a well one needs to move closer in.
- For that SEISMIC is the way to go. It is very expensive but will reveal structures/traps capable to hold hydrocarbons.
- However seismic does in general not proof the presence of hydrocarbons in a detected trap.
- To better the chances for sucess one can then use close in geochemical and microbial surveys. They are capable to confirm the presence t of hydrocarbons leaking from a deposit up to the surface.

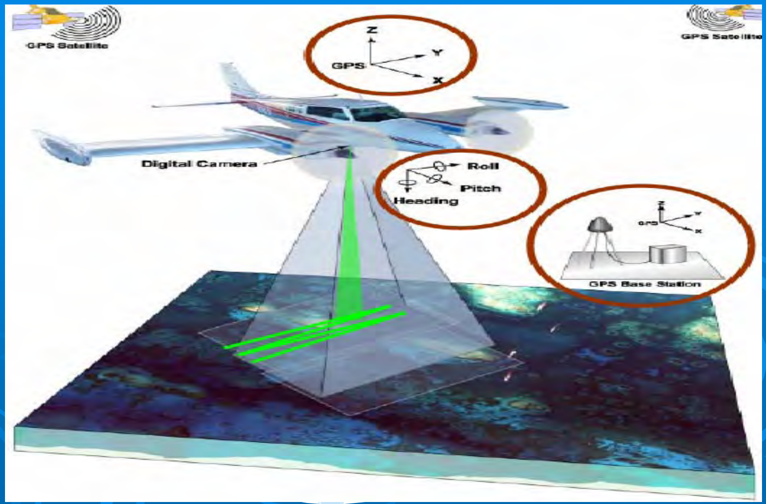
We propose now a new technology which combines the best of both worlds. It is a remote airborne sensing technology but it puts its very sensitive sensors on the ground and therefore directly on top of any hydrocarbon deposit.

It is composed of harmless live soil bacteria which function as fluorescent biosensors to find trace amounts of hydrocarbons and an airborne scanning Laser system (Lidar) to detect in full flight those biosensors on the ground

The concept is based on our recent work in the field of humanitarian demining where we use the trace detection of explosives to pinpoint the location of landmines.

What we are currently doing in humanitarian demining:

- Establish a new remote sensing technology suitable for the stand off detection of trace explosives leaking as a tell tale signal from landmines of all types and builds.
- For that we join for the first time two high technologies …..
- We employ microbiology to produce a genetically engineered but safe soil bacterium to use it as a sensitive fluorescent live **biosensor** for trace explosives.
- We will use commercially available **airborne laser technology (LIDAR)** and modify it to search rapidly and over wide areas for fluorescent biosensors on the ground indicating the presence and location of landmines.



What are biosensors?

- A device that uses biological materials to detect and monitor the presence of chemicals or molecules in a substance.
- This could be for example an enzyme-based or antibody-based sensor "mounted" in a "lab on a chip" to detect narcotics in the sweat of a suspect or Antrax spores in the air.

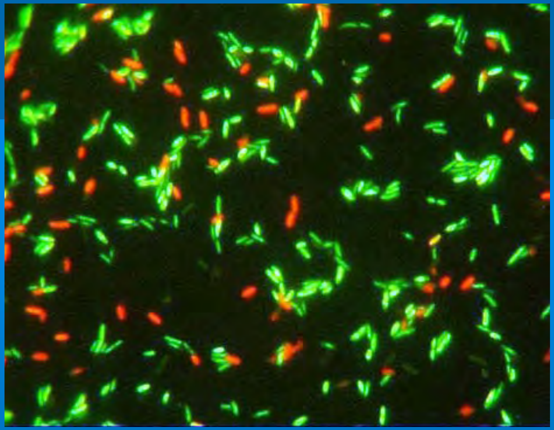
What are live biosensors?

- A living organism or a single living cell capable to sense and signal by itself the presence of a substance in the environment it is moving in.



How can a single living cell be made to signal something we can then detect?

- By using the naturally acquired and genetically encoded capability of a cell to sense a substance and …
- By genetically tying the sensing process to a second and artificially introduced biological signaling process which yields fluorescent proteins as a detectable signal.



Bacteria labeled with green and red fluorescent proteins

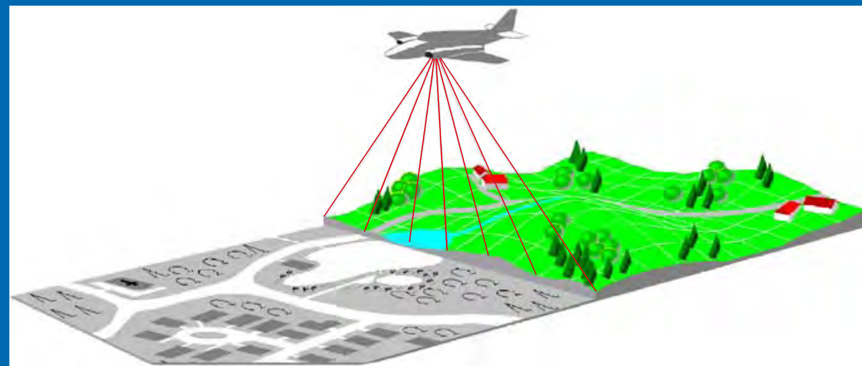
Braincells of a mouse labeled with fluorescent proteins

Fluorescent mice

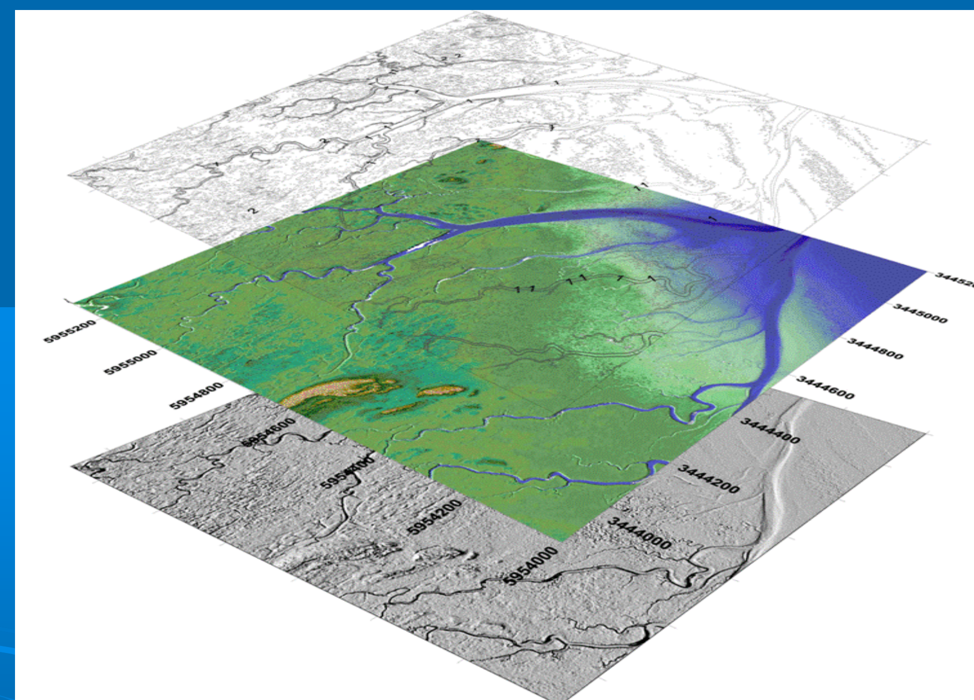
What is an airborne LIDAR?

- The acronym LIDAR stands for **L**<u>**i**</u>ght **D**etection **a**nd **R**anging
- Airborne LIDAR systems integrate a pulsed laser scanner, a Global Positioning System (GPS) and an Inertial Measurement Unit (IMU).
- A modern airborne LIDAR sends typically about 100.000 ultra short laser pulses per second to the ground. It measures the total traveltime of each individual light pulse from the LIDAR to the ground and back as a reflection to the receiver unit of the LIDAR. Depending on the flight altitude and flight speed 5 – 10 precision distance measurements per square meter are sampled.
- Using ultra precise navigation giving the position and orientation of the aircraft for each time a laser pulse was fired to the ground the system is capable to calculate the position and distance of each laser reflection point on the ground. These data are then used to generate Digital Elevation Models describing the overflown land surface with great detail. Digital Elevation Models can be worked with using normal office computers or lap tops
- LIDARS were initially developed for military applications like target acquisition and precision navigation of cruise missiles. A special application was submarine hunting using green laser light. We eventually will use such a system and modify it to hunt landmines.
- Civilian applications nowadays are for example the precision mapping of urban areas, flood plane mapping, corridor planning and open pit mining.

Digital Elevation Model Samples

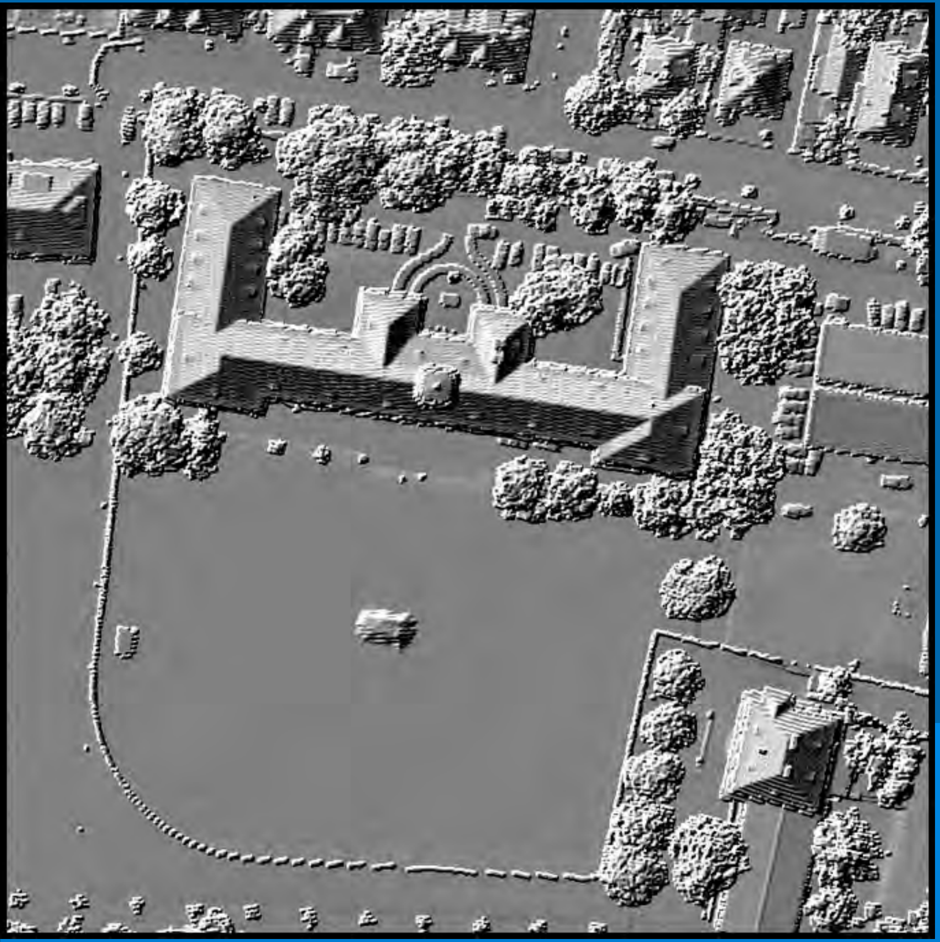


Elevations are color coded



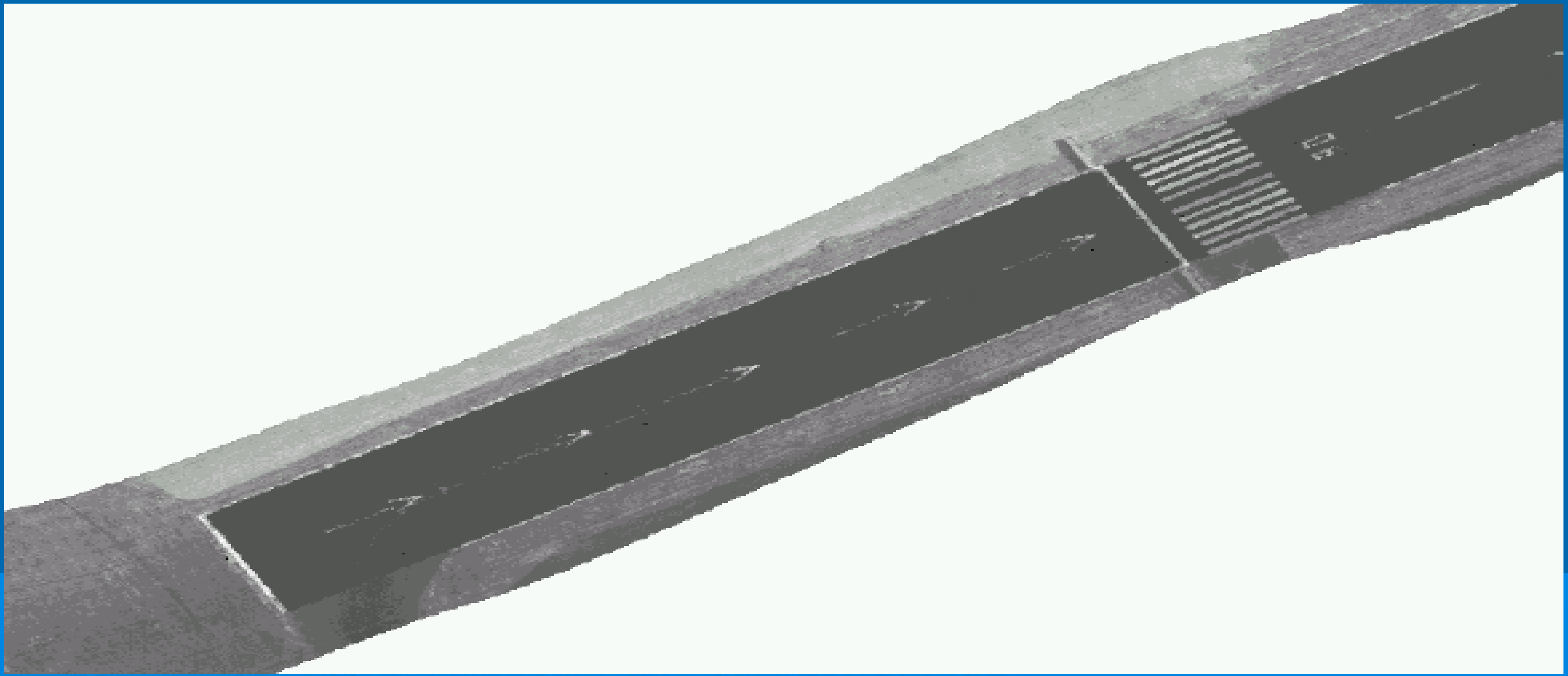
Three versions of the same model stacked

Digital Elevation Model Samples



- A LIDAR can penetrate the canopy of a forest and in fact detect and look at the ground!!!
- *Golden rule*: if an observer in a forest can see small patches of the sky above him the LIDAR can see the ground – and fluorescent biosensors on the ground!

Measuring fluorescence intensity with a LIDAR

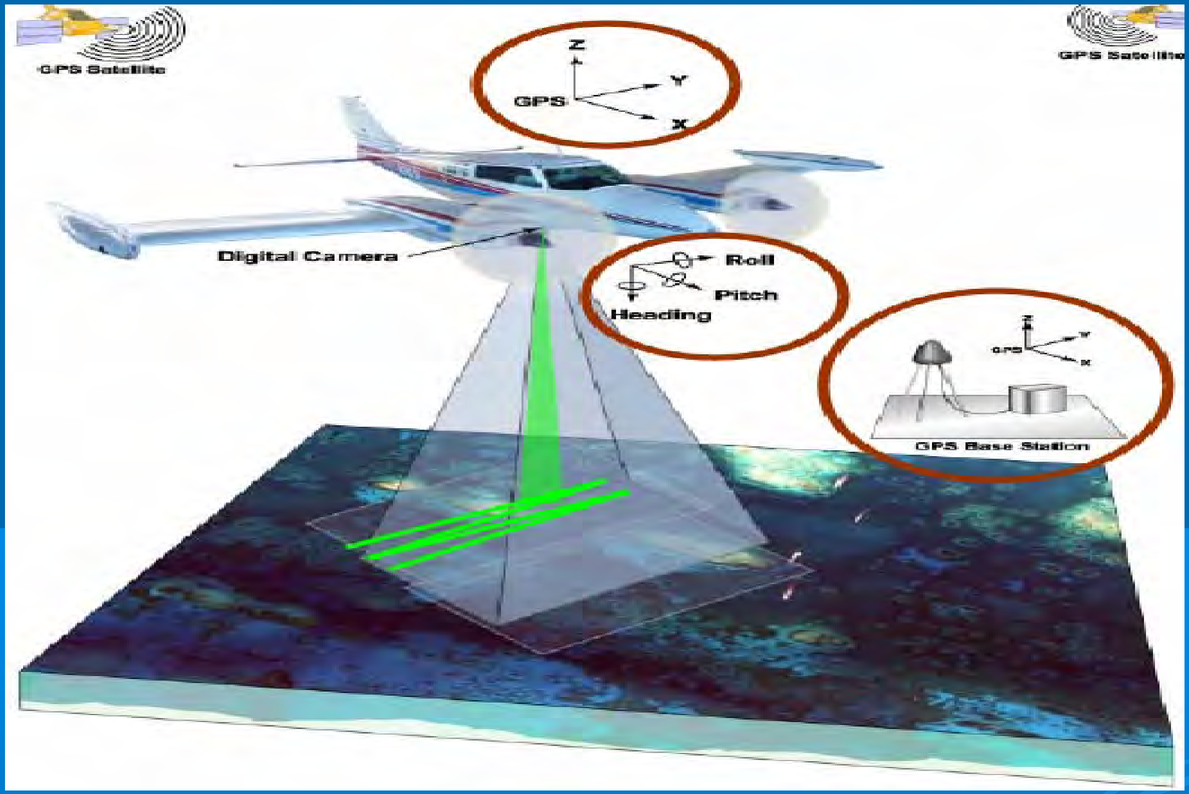


- Shown is a Digital Elevation Model of an airstrip.
- In this case no color coded elevations are shown but gray coded intensities of the reflected laser light entering the receiver.
- The painted surfaces on the strip yield the highest reflection intensities.
- This functionality of a LIDAR can be used to detect fluorescent light from biosensors and its intensities.

How can biosensors be spread quickly over wide areas of interest?

- Daily capacity of a single plane estimated to be 5 square kilometers or more depending on the package of the biosensor

How can fluorescent biosensors on the ground be detected from the air and in full flight?



- A scanning pulsed laser system scans measures the surface and at the same time excites and detects fluorescent light in biosensors
- Flight altitude 800 meters, daily capacity 100 square kilometers

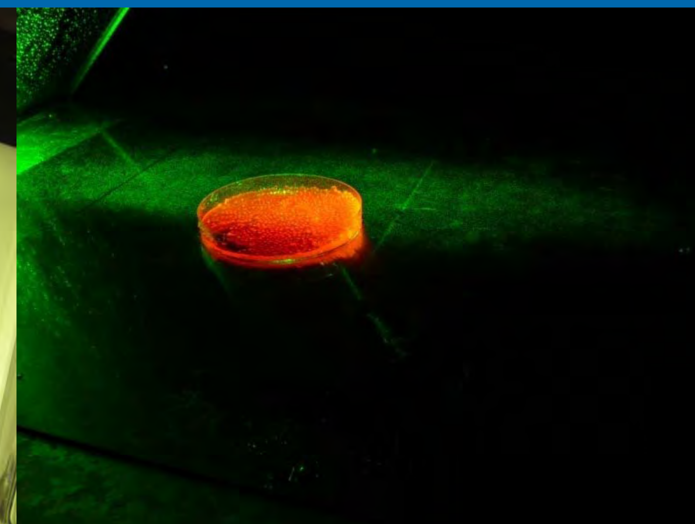
Preliminary results after two years of research **Biosensor**:

- A functional and safe fluorescent biosensor for traces of TNT and DNT was developed and tested in bio-security labs at Fraunhofer Institute for Microbiology in Germany.
- The biosensor is based on the begnin soil bacterium *Pseudomonas putida* and produces a large amount of bright red fluorescent proteins upon contact with TNT or DNT.
- The biosensor is sensitive enough to detect TNT and DNT in concentrations between 1ppm – 10 ppm dissolved in liquids and 10 ppm dissolved in soil (1 ppm==1mg/kg==1mg/ltr.)
- ***This is in the range of reported TNT and DNT concentrations found in soils next to landmines***.
- As our biosensors settle on the soil surface we might benefit from a process where TNT molecules dissolved in water get enriched at the surface in dried up puddles.

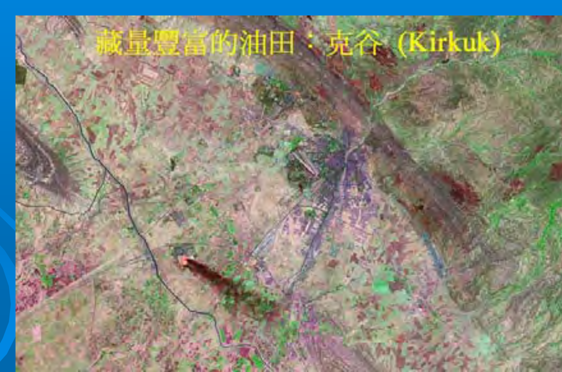
Preliminary results after two years of research <u>**Laser scanner**</u>:

- Development of a laboratory scale laser scanner set up in a dedicated biosafety laboratory at the Fraunhofer Institute for Lasertechnology in Germany.
- The laser scanner was used to test and calibrate the genetically produced live fluorescent biosensor for TNT and DNT.
- Dectetion of the live fluorescent biosensor in the lab over a distance of 12 meters (we consider that already a safe stand off distance).
- Development of a mock up biosensor exhibiting the same spectral response as the genetically modified live biosensor. This mock up biosensor could be used without any restrictions outside of a biosafety lab.
- Outdoor tests of the mock up biosensor and detection of small volumes of mock up biosensors over a distance of 300 meters using a stationary mounted airborne fluorescence LIDAR employed by the German government in patrol flights over German costal waters to detect oil spills.
- <u>***Proof of principle for the airborne detection of fluorescent biosensors achieved!***</u>

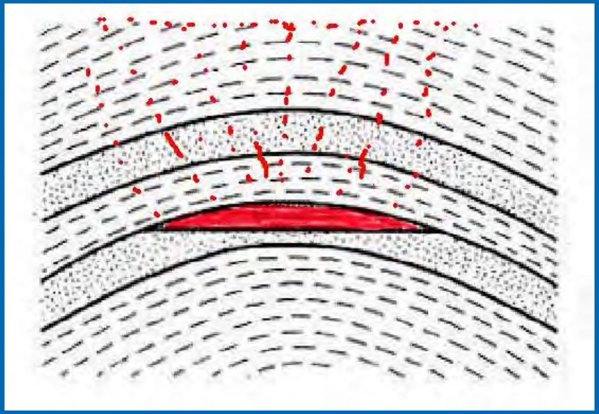
Of course soil bacteria can also be engineered to detect traces of hydrocarbons (C1-C4)

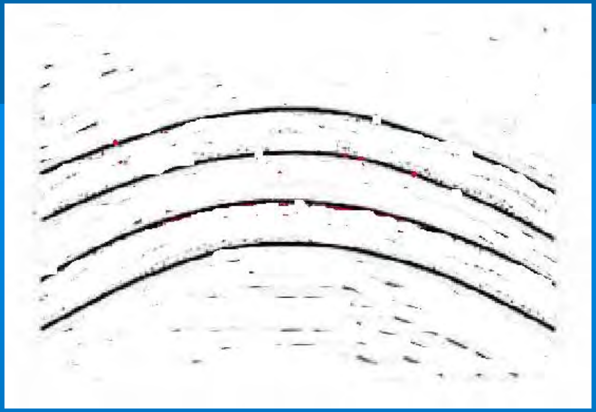


After all size really does not matter



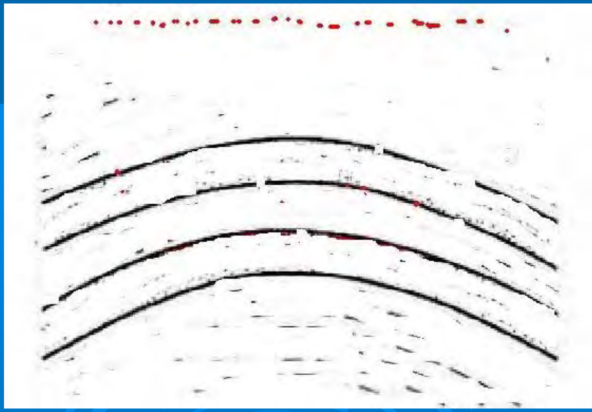
Principal section of a trap filled with oil, leaking trace hydrocarbons C1 – C4 to the surface





This is what seismic sees

This is what a fluorescent biosensors on the surface would signal



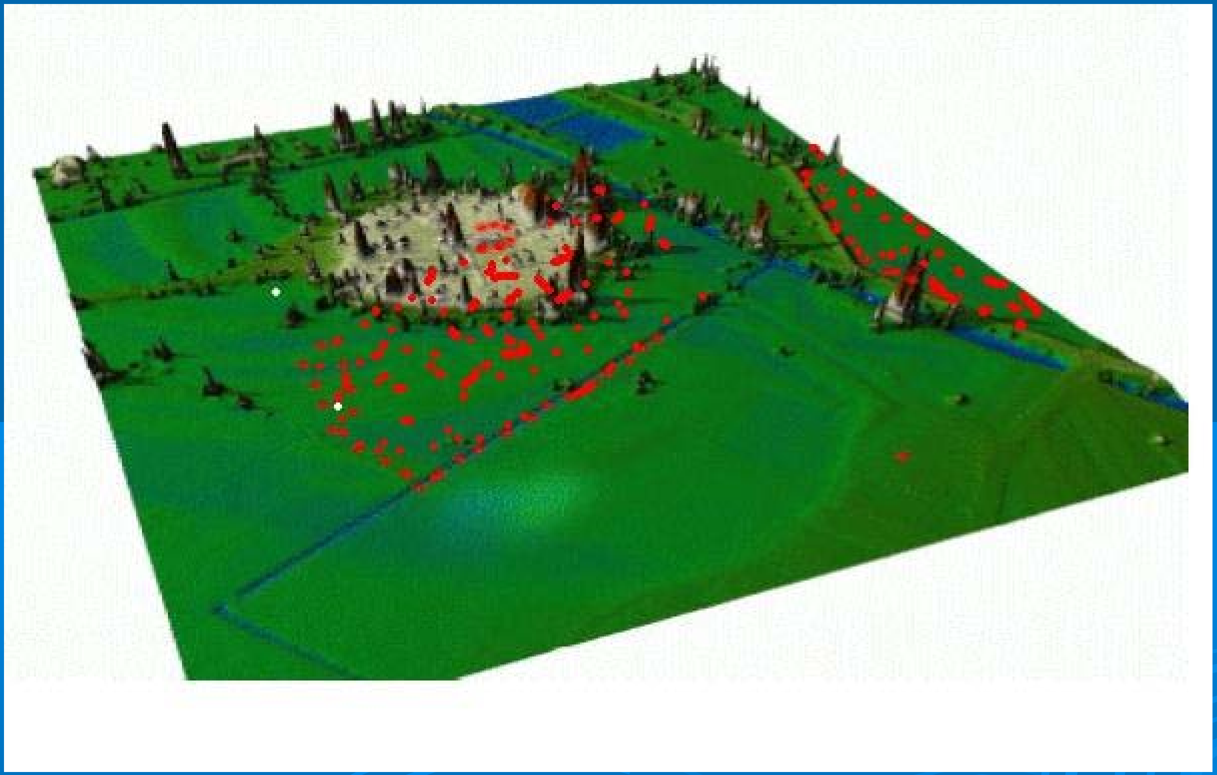
This is what both technologies combined would see

C1-C4 are very small molecules – they can be expected to leave the oilfield directly up to the surface driven by buoyancy and to a lesser extent by diffusion

There is no such thing as sealing faults as far as trace detection of micro seeps is concerned. We therefore expect that faults will nicely show up on digital elevation models with elevated levels of fluorescent light

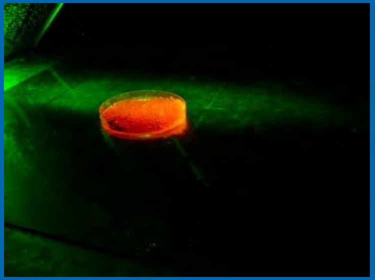
Our biosensor for trace explosives is dose depended – so will be the biosensor for hydrocarbons

A photo shopped digital elevation model with fluorescent biosensors on the ground indicating an underlying oil or gas deposit



Up to now this is still science fiction – but near term and based on very solid research results from our research on land mine detection

- Out door tests of mock up biosensor at Bremerhaven airport.
- Easy detection at a distance of 300 m



The target: a petri dish filled with mock up sensors containing fluorescent proteins produced by the real biosensor

- Model of biosensor dispersion using small “Caviar sized” alginate pellets containing initially about 10.000 biosensors in each pellet.
- Biosensors still multiply in pellets reaching a density of 1.000.000 biosensors and more in a single pellet.

This is the first time that fluorescent live soil bacteria and an airborne Laser scanner are combined to form a new sensing technology.

Its general advantages are:

Extremely high productivity

Extremely high spatial resolution (not really necessary in oil exploration)

No foot on the ground – safe in hostile environments

Detects the uniform signal of all hydrocarbon deposits – short chained hydrocarbons which are very mobile and which penetrate cap rocks with ease

Detects not only structural traps but also those hard to explore stratigraphic traps

Should be perfect to find sweet spots in shale gas plays because elevated leaking rates show up as elevated fluorescent light intensities

What about the public perceptions and acceptance of genetically modified bacteria as biosensors in oil exploration?

- Preliminary talks with the German licensing body for genetically modified organisms indicated that against the background of humanitarian demining no problems are to be expected to obtain single permits for release of the biosensors into the wild and subsequently an unlimited license for the use of the biosensors in Humanitarian Demining and other applications (for example homeland security).
- Elsewhere genetically modified live soil bacteria are already added to soils to enhance nitrogene fixation in plant roots.
- Genetical modified soil bacteria are also used as bio-pestizides or bio-larvaecides
- Genetically modified live viruses have been release all over Europe to vaccinate foxes against rabies. Baits containing the genetically modified live virus were dropped from aircrafts over wide forest areas.
- Genetically modified bacteria and animals are used for biopharm purposes to produce human and animal pharmaceuticals.
- Fluorescent “GLO-Fish” are freely available in the US as pets

any ?