The surgeon giving his patients VR instead of sedatives

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By Jo Marchant | From Mosaic
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Ana Maria has never been to Machu Picchu. The 61-year-oldalways wanted to visit the mountain ruins but she suffers from hypertension, and doctors warned that the extreme altitude could cause her blood pressure to rise dangerously high.



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The surgeon giving his patients VR instead of sedatives

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of-sedatives 1/41



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BBC - Future - The surgeon giving his patients VR instead of sedatives Today, dressed in a white gown and hairnet, she wil explore its ancient wal s and pyramids for the first time.

She's in a private medical clinic in Mexico City, and laughs nervously as she's wheeled into a windowless operating room. The surgeon takes a Sharpie and draws a large circle on her left thigh, paints on several layers of iodine, then injects a local anaesthetic into the skin. Inside the circle is a fatty lump, a lipoma around 6cm across, which he is about to remove.

Ana wil be awake for the operation, and she's feeling scared. As the surgeon readies his scalpel, her blood pressure is 183/93, even higher than usual. Patients undergoing procedures like this often have to be sedated to cope with the pain and anxiety of being under the knife, but not today. Instead, Jose Luis Mosso Vazquez, who is supervising the operation, fits a sleek, black headset over Ana's eyes and adjusts the straps.

Immersed in a three-dimensional re-creation of Machu Picchu, patients are oblivious to the surgeon and medical equipment around them (Credit: Chester Holme) www.bbc.com/future/story/20170202-the-surgeon-using-virtual-reality-instead-of-sedatives 2/41

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BBC - Future - The surgeon giving his patients VR instead of sedatives The surgeon makes his first cut and blood spil s down Ana's leg. She's surrounded by medical equipment – stools, trol eys, swabs, syringes – with super-bright surgical lamps suspended above the bed. Her vital signs are displayed on monitors just behind. But Ana is oblivious. She's immersed in a three-dimensional re-creation of Machu Picchu. She begins her journey with a breathtaking aerial view of the ancient city clinging to the mountainside, before swooping down to explore the details of stepped terraces, moss-covered wal s and tiny stone huts.

Mosso watches her careful y. A 54-year-old surgeon at Panamerican University in Mexico City, he's on a mission to bring virtual reality into the operating room.

Mosso is using VR as a high-tech distraction technique, al owing surgeons to carry out operations that would normal y require powerful painkil ers and sedatives, with nothing more than local anaesthetic. He's trying to prove that reducing drug doses in this way not only slashes costs for Mexico's cash-strapped hospitals, but cuts complications and recovery times for patients too.

Mosso has prepared an intravenous

line just in case the VR headset isn't enough

But with Ana, Mosso is not sure if the headset wil be enough. He hopes the virtual reality wil help her avoid extra medication – but if she becomes anxious during the surgery, her already-high vital signs might spike. He has prepared an intravenous line just in case, ready to administer emergency medication if required.

But it isn't. The surgeon pul s a large, pearly glob of tissue from Ana's thigh, his fingers easing under her skin as he careful y snips it free. Then he mops the blood and stitches the wound. The procedure has taken just 20 minutes, and there are smiles al round as Ana thanks the team. Engrossed in the virtual reality, she www.bbc.com/future/story/20170202-the-surgeon-using-virtual-reality-instead-of-sedatives 3/41

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BBC - Future - The surgeon giving his patients VR instead of sedatives barely noticed the scalpel slicing her flesh. "I was transported," she says.

"Normal y I'm very stressed, but now I feel so, so relaxed."

The monitors back up her story. Throughout the surgery, her blood pressure actual y fel .

The amazing Spider-Man

In 2004, Mosso bought a Spider-Man game for his eldest son, and his life and career path changed. The game involved images projected onto a head-mounted display – an early form of VR. Mosso was struck by how immersed his son became in the game. "His Mom cal ed him to go to dinner and he didn't hear her, nothing," he says. "I thought, what if I use this on a patient?"

Mosso began using the game during upper gastrointestinal endoscopies, in which a flexible tube with a camera on the end is fed through a patient's throat into their stomach. The experience can be unpleasant and distressing. Patients often require sedation but Mosso encouraged them to play the Spider-Man game instead.

He asked the patients to score their pain and anxiety during the procedure and in 2006 presented his results at the Medicine Meets Virtual Reality conference in California. The idea of using VR to reduce the distress of medical procedures was pioneered at the University of Seattle, Washington, where cognitive psychologist Hunter Hoffman and col eagues have developed a VR game cal ed SnowWorld,

to help patients endure wound care for severe burns. Hoffman's team have shown in trials that SnowWorld reduces patients' pain during wound-care sessions by up to 50%, as wel as reducing pain-related brain activity.

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BBC - Future - The surgeon giving his patients VR instead of sedatives The virtual world has to be relaxing – a shooter game, no matter how distracting, can increase the risk of bleeding if the excitement raises blood pressure (Credit:Chester Holme) But there has been relatively little work in other medical contexts. At the 2006

conference, Mosso met Albert "Skip" Rizzo, a psychologist (and now director of medical VR) at the University of Southern California, who had been doing similar research with endoscopies. "He presented 10 cases," says Mosso. "I presented 200." Rizzo showed Mosso the expensive, state-of-the-art head-mounted displays he was using. "It was another world," says Mosso. But then

Rizzo revealed the equipment with which he had begun – it was the exact same Spider-Man game.

Impressed by Mosso's work, Rizzo donated a headset to him and persuaded a col eague, Brenda Wiederhold of the Virtual Reality Medical Center in San Diego, to let Mosso use some virtual worlds she had developed specifical y for pain relief.

Mosso returned to Mexico with his new equipment and started to use VR in a much wider range of situations, from childbirth to recovery from heart surgery. It helped to relax patients across the board, but some of his most successful results www.bbc.com/future/story/20170202-the-surgeon-using-virtual-reality-instead-of-sedatives 5/41

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BBC - Future - The surgeon giving his patients VR instead of sedatives were in minor day surgery, procedures such as removing lipomas, cysts and hernias, during which patients are awake but often sedated.

Patients using VR reported 24% less

pain and anxiety during surgery

He used a virtual scenario developed by Wiederhold cal ed Enchanted Forest, in which users can explore rivers, lakes, trees and mountains. The virtual world has to be relaxing, says Mosso. A shooter game, no matter how distracting, might increase the risk of uncontrol ed bleeding if the excitement raised patients' blood pressure.

VR is now being studied by teams around the world to relieve pain in medical situations such as wound care and dentistry, as wel as in chronic conditions such as phantom limb pain. But Mosso is stil the only researcher to have published results on the use of VR during surgery. In one study of 140 patients he found that those using VR reported 24% less pain and anxiety during surgery than a control group. He got similar results in a smal er randomised trial.

Offering patients VR also halved the amount of sedation they needed, and in many cases avoided its use completely. That represents an important cost saving for the clinics in which Mosso works – sedative drugs such as fentanyl and midazolam are “very, very expensive”, he says.He estimates that VR reduces the cost of surgery by around a quarter. Cutting drug doses should also reduce risks of complications and recovery times for patients. Mosso is planning further trials to test this, but in general, he says, patients can go home an hour after surgery if they receive only local anaesthetic, whereas those who are sedated often need a whole day to recover.

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BBC - Future - The surgeon giving his patients VR instead of sedatives Packing his jeep with food, clothes and medical equipment, Mosso heads into the mountains to bring his VR surgery to a vil age with no doctors (Credit: Chester Holme)

“It cuts down on the cost, on the recovery time, and on the complications,” says Wiederhold. “It’s incredible. We stil have not done that here in the US.” Gregorio Obrador, dean of medicine at Panamerican University, is impressed too. He wasn’t sure what to make of it at first. “I thought it was a little goofy,” he says. “I’m accustomed to giving pain medication.” But after looking at the literature on VR

and pain relief, Obrador is now convinced.

Overal , Mosso has now carried out more than 350 surgeries using VR, and says he’d love to see it used as a routine component of pain relief in operating rooms.

But he has a bigger vision. What if VR could be more than an alternative to sedation during hospital surgeries? Could it help him to bring surgery to patients where sedation isn’t possible, where there are no hospitals at al ?

Road trip

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BBC - Future - The surgeon giving his patients VR instead of sedatives Mosso’s Jeep Cherokee is ful to bursting. Tents, plastic food boxes, surgical equipment, medication, sanitary products and bags fil ed with clothes, sweaters and shoes are squeezed into every available space inside and tied precariously to the roof. On the back seat are Mosso’s wife, Veronica – a gynaecologist – their youngest son, Olivier, and, to keep the nine-year-old entertained, two baby iguanas recently captured from the forest near Acapulco, confined for the journey in a green net bag.

There’s a long drive ahead. We are going to El Tepeyac, an isolated vil age hundreds of kilometres away in the mountains of Guerrero state. It’s home to an indigenous Me’phaa community (often cal ed Tlapaneco by outsiders), one of

Mexico's poorest. "They have been forgotten," says Mosso. "They live with cold, on top of the mountain. They don't have hospitals, clinics, nothing."

What if VR could bring surgery to

patients where sedation isn't

possible, where there are no

hospitals?

As the high-rise blocks of Mexico City give way to sprawling shanty towns and then forested mountains, Mosso tel s me about his father. He was born close to El Tepeyac but left when he was 13, eventual y becoming a teacher near Acapulco.

He returned briefly to his childhood home after getting married, but never visited again until Mosso took him 40 years later.

Mosso was shocked by the poverty he saw, with dwel ings that he felt could barely be described as houses. The vil agers asked him to examine a patient, an old woman with a fever who was lying in a puddle on the floor (there had been a recent flood, and it was the only place close to the fire). She had pneumonia and Mosso told them there was nothing he could do. "She was my aunt," he says.

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18.7.2019

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“She died a few weeks later.” He pauses, eyes fixed on the road. “That’s why I go back. Because of my aunt.”

In 2000, Mosso and Veronica began to travel to El Tepeyac every few months.

They helped the vil agers to build and stock a basic medical clinic, and carried out simple surgeries. But a few years ago their trips stopped, due to a sharp rise in violence from the country’s drug cartels. These organised criminal groups have been active across Mexico since the 1990s, producing heroin from poppies grown in the mountains here and exporting it to the US and Europe. Any violence was traditional y directed mostly at the authorities and each other, but since 2009 the cartels have increasingly targeted the general population with extortion and kidnappings.

Mosso gets through around 20 patients during the morning and performs minor surgery on several of them with the help of his VR headset (Credit: Chester

Holme) The threat of violence is now routine for many Mexicans. The news here is fil ed with beheadings, mutilations and disappearances. On the freeway in the outskirts www.bbc.com/future/story/20170202-the-surgeon-using-virtual-reality-instead-of-sedatives 9/41

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BBC - Future - The surgeon giving his patients VR instead of sedatives of Mexico City the day before, we had passed a group of four men, calmly crossing on foot between the busy traffic. One of them carried a young woman over his shoulder, either dead or unconscious, her dark hair spil ing down past his hips. Mosso shrugged; for him the sight was nothing unusual. He works weekends at a hospital in this area and says he once had to order his surgical team to flee the operating room when a gunman entered the building, intent on kil ing their patient.

But the security situation is particularly bad in Guerrero, which is the country's most violent state, with one of the highest murder rates in the world.

According to a 2015 report by anthropologist Chris Kyle of the University of Alabama, Birmingham, il egal roadblocks, carjackings and kidnappings are routine here. The police have lost control, Kyle says, and there is "near complete impunity" for the perpetrators. In 2009, Mosso and Veronica reluctantly decided that it was too dangerous to travel. "We were coming to El Tepeyac four times a year," he says. "When the narc began, no more."

He once had to order his surgical

team to ee the operating room

when a gunman entered the building

But he's desperate to see his family, and worried about the health of the vil agers.

So although the security situation hasn't improved, he is now attempting the trip

again. We take a roundabout route because the most direct way – the main route for transporting opium out of the region – is too dangerous. We travel by daylight and eat on the move, making just one brief stop, in a deserted lay-by, during the nine-hour drive.

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BBC - Future - The surgeon giving his patients VR instead of sedatives When we reach the steep streets of Tlapa, Mosso visibly relaxes.In this largely indigenous area, self-organised community police groups have been relatively successful in limiting the violence of the cartels. From Tlapa, the road gets higher and rougher as the sun sets, eventual y becoming a narrow, winding track of mud and stones.

We arrive to find El Tepeyac in darkness – the only power line was recently blown down in a storm. The vil agers line up to meet us with flashlights, wide eyes and smiles looming out of the black. The welcome is a little awkward – many of them don't speak Spanish, and Mosso doesn't speak Me'phaa – until they direct us to a long, plastic table beneath a high shelter and feed us chicken soup and tortil as, freshly cooked over a fire, with steaming lemon tea.

Doctor in the house

The sun rises to reveal the centre of El Tepeyac as a handful of brightly painted concrete buildings surrounding a covered basketbal court, where communal meals and functions are held. Around 150 people live here, their homes scattered across the mountainside, each with space for vegetables, chickens and cows, and a large rain butt for fresh water.

Not long after breakfast, Mosso gets to work. We walk down a muddy track to a single-storey building with two rooms, bare concrete floors and shelves stacked with pil s.Would-be patients – some are from El Tepeyac, others have walked

from neighbouring vil ages – wait in an open porch while Mosso and Veronica set up tables and chairs inside. This morning, the two doctors wil each hold an open clinic.

Mosso gets through around 20 patients during the morning. One has red tracks on his thighs from the claws of a tarantula that crawled into his trousers while he was working in the fields. He has since developed sensitive skin and back pain, which he fears is due to the spider's poison. Mosso prescribes antibiotics for www.bbc.com/future/story/20170202-the-surgeon-using-virtual-reality-instead-of-sedatives 11/41



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BBC - Future - The surgeon giving his patients VR instead of sedatives cases of parasitosis and kidney infection. An old man comes in with a hernia untreated for 20 years. The nearest doctor is in Tlapa – an hour's drive away but a difficult journey without a car. He also identifies a handful of cases suitable for surgery here in El Tepeyac.

When the headset is put on the girl's head she is immediately quite – "I see fishes,"

she says (Credit: Chester Holme)

After a morning without power, the lights have now come back on. The clinic floor is briskly swept as Mosso and Veronica put on scrubs and lay out scalpels. A nine-year-old girl named Joanna is on a bed by the window, screaming for her mother. Mosso is going to remove a lump of cartilage from behind her ear. She is wearing jeans and a T-shirt, and has bare, dirty feet. Through the window children are playing, adults sit in chairs sharing home-brewed tequila, and the mountains stretch for miles.

Veronica fits the VR headset and the girl is immediately quiet. “I see fishes,” she says. “I see water.” Mosso has chosen for her an island world, with stone ruins www.bbc.com/future/story/20170202-the-surgeon-using-virtual-reality-instead-of-sedatives 12/41

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BBC - Future - The surgeon giving his patients VR instead of sedatives and tropical fish beneath the sea. She remains stil and calm until Mosso has finished stitching, then describes her experience. “I have never seen the sea,” she says. “I liked it. I felt that the water was warm.”

Then there are several lipomas to remove. These benign tumours are mostly harmless but if they cause pain, Mosso recommends surgery. He operates on a 54-year-old kindergarten teacher with two lipomas on her arm, and a man in his 20s who studied in Tlapa and has played video games before. The man is sceptical about the VR at first, but says it was better than he expected it to be after his operation.

The girl remains stil and calm in an undersea world until Mosso has

nished stitching

Next is 31-year-old Oliveria, her dark, curly hair tamed in silver butterfly clips. She has four children, works as a farmer and has walked from a vil age one-and-a-

half hours to the south. She has a lipoma deep in her back, which hurts when she moves. It is a slightly trickier case than the others but the lump is likely to keep growing, so Mosso thinks it's best to remove it now.

Oliveria lies on her front in black jeans and a bra as Veronica fits the headset. She enters the same undersea world as Joanna. Mosso injects local anaesthetic into the lump, makes a cut, and his white-gloved finger disappears to the knuckle. He feels around. "I'l have to open up the muscle," he concludes. He extends the cut, pul s open the flesh with metal brackets and reaches in deeper. Eventual y, he manages to pul the fatty bal free. Veronica holds it with tweezers as Mosso cuts it out: success.

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BBC - Future - The surgeon giving his patients VR instead of sedatives But the undersea world has been replaced by an error message. The laptop wasn't plugged in, and the battery is about to fail. A few seconds later, Mosso and Veronica realise that Oliveria has lost consciousness.

Everyone is moving. They turn the patient onto her back, Mosso rubbing her chest and shouting "Vamos a la casa!" while Veronica waves alcohol-soaked cotton wool under her nose. The pain has triggered a sudden drop in Oliveria's blood pressure, causing her to faint. Mosso inserts an intravenous line with fluid to restore the pressure. Oliveria moans, and bats away the cotton wool. "Breathe slowly," says Veronica. Mosso swishes a fly from her face.

After a few minutes, they rol Oliveria onto her side to sew up the wound. Mosso doesn't have the facilities here to sedate her, or offer her any painkil ers more powerful than the local anaesthetic, so he plugs in the laptop and switches the VR

back on. Veronica keeps Oliveria talking as Mosso works. “What do you see?”

she asks. “Fishes, water, stones,” Oliveria replies. Then they help her to her feet and walk her to a bed in the next room. There’s no stand or hook for the IV line so after some searching Oliveria ties it to an old floor lamp, which he balances on a table by the bed, next to Olivier’s iguanas, happily munching lettuce on a plate.

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BBC - Future - The surgeon giving his patients VR instead of sedatives After her operation, Oliveria is helped home with her IV line (Credit: Chester Holme)

“It looks easy, but we never know at what moment we can have a surprise,” says Mosso when the crisis is over. “In a hospital I’m relaxed, because the monitor tel s me the patient’s heart rate, breathing, blood oxygen. There’s an anaesthesiologist, scrub nurse, other surgeons. But here, we’re far away from the hospital and my col eagues. With or without surprises, I’m worried. What if something happens

here and I don't have solutions? Tlapa is far away."

Does he think it's worth the risks? "Yes," he says, without hesitation. "They don't have the opportunity for surgery otherwise. And the risk is very low. In 350

patients, I just had one with this complication."

Half an hour later, Oliveria is ready to leave. "I didn't know I was going to have surgery today," she says to Mosso and Veronica. "Thank you." Mosso gives her paracetamol and antibiotics, and instructs her to take a taxi home. She has asked to keep the lipoma so he hands her the twisted, blood-stained lobes in a smal pot of alcohol. Her hands are shaking as she takes it**.**

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BBC - Future - The surgeon giving his patients VR instead of sedatives **Send off**

Next morning there's an impromptu farewel party on the basketbal court. The vil age brass band plays and Mosso joins in with the traditional Mexican dancing.

Stil , he wants to leave early – despite the circuitous route he has planned, it is unwise to be on the roads around Acapulco after nightfal . But there's another line of people at the clinic. Veronica hands out the clothes and supplies from the Jeep

– donations from their son's school – while Mosso sees the patients. There's one more case for surgery: a boy with a haemangioma – a benign tumour of blood vessels – on his head. There isn't a strong medical need to remove it, but the boy is being bul ied by his friends and his mother is desperate.

Mosso agrees to the surgery, but once that's done more patients arrive – they've walked an hour to see him. Mosso says no. It's already early afternoon, we have to

go. We drive seven hours without stopping, the air ever warmer as we leave the mountains and climb down towards the sea. He's agitated, pushing 90mph along the long, straight coastal road, but we lose the race. The sun sets and we speed towards the city in darkness. Then cars coming the other way begin to flash their headlights, and shortly afterwards we're waved to a halt by a group of armed men in military attire.

Mosso knows the dril . Quickly he opens his window, flips on the interior light and cal s his son into the front. They're looking for enemies, he says. As long as they can see we're not hiding anything, they should let us through. Sure enough, the gunman looks inside and waves us on.

The gunman looks inside, sees we're

not hiding anything and waves us on

Once at his home in Acapulco, in a gated apartment complex, Mosso reflects on the trip. "It was successful," he says. "I'm happy with the results." He has col ected www.bbc.com/future/story/20170202-the-surgeon-using-virtual-reality-instead-of-sedatives 16/41



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BBC - Future - The surgeon giving his patients VR instead of sedatives data on al of the surgeries he carried out, and hopes that his experiences wil encourage the use of VR to help patients in other under-resourced communities around the world.

In the last year or two, the release of cheap devices that work with a smartphone

– such as the Samsung Gear VR, which costs less than £100, and the basic Google Cardboard, which costs just £3 – plus the growing number of virtual

worlds freely available online have transformed access to the technology. “When we started, virtual reality was expensive, difficult to get and difficult to set up,”

says Mosso. “Today, everyone can use it.” Although Mosso connected his headset to a laptop in El Tepeyac, he has previously shown that the technique also works running on a phone. “There’s no heavy equipment,” he says. “It’s very easy to use.”

Meanwhile he is already making plans to return to El Tepeyac. During our trip, he met with a local government representative who wants him to visit not just that vil age but neighbouring indigenous communities too. That would take time and money that Mosso doesn’t have, but he’s trying to convince some of his col eagues in Mexico City to help, and hopes that soon he’l be able to return to Guerrero with a team of surgeons, perhaps in spring 2017. He dreams of one day reaching even more remote communities – vil ages deep in the mountains that he has heard about but never visited, that have practical y no contact with the outside world.

Mosso is wel aware that it wil take more than VR to solve the problems of the people of El Tepeyac – and his country. But he’s helping them in the only way he knows.

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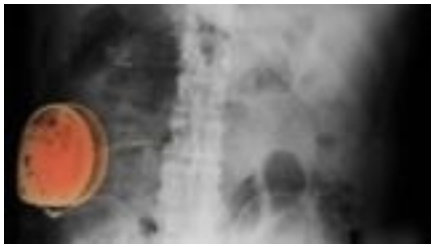
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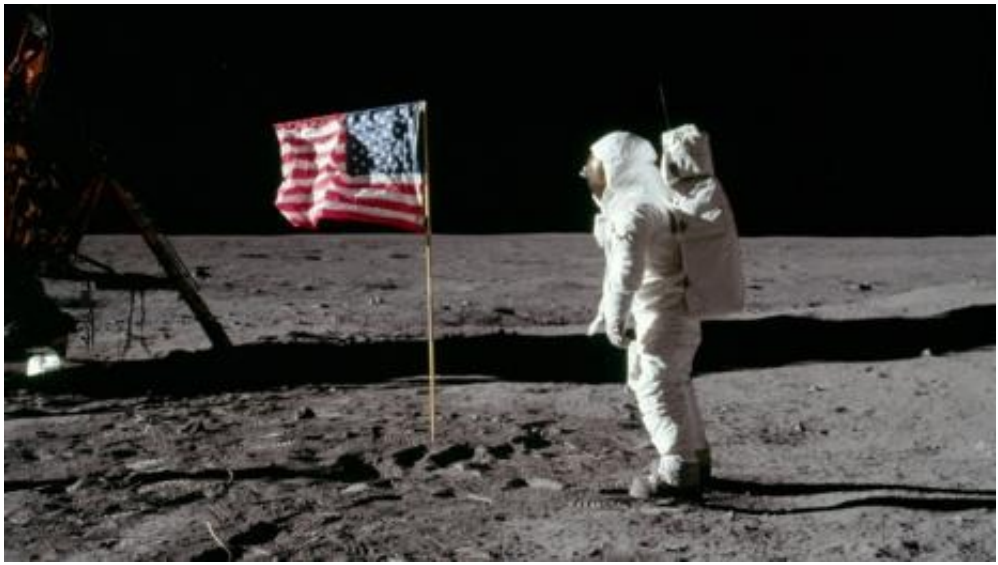
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