PhD lightning talk

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AIRBUS

Context

Landing phase

Buenos Aires - Argentina

Landing phase

Buenos Aires - Argentina

Runway position

1- longitude
2- latitude
3- altitude

Aircraft position

1- longitude
2- latitude
3- altitude

Aircraft inclinaison

1- yaw
2- pitch
3- roll

Landing phase

Buenos Aires - Argentina

Runway position

1- longitude	Known
2- latitude	Known
3- altitude	Known

Aircraft position

1- longitude	Known
2- latitude	Known
3- altitude	Known

Aircraft inclinaison

1- yaw
2- pitch
3- roll

Landing phase

Buenos Aires - Argentina

Runway position

1- longitude	Known
2- latitude	Known
3- altitude	Known

Aircraft position

1- longitude	Known
2- latitude	Known
3- altitude	Known

Aircraft inclinaison

1- yaw	Known
2- pitch	Known
3- roll	**Unknown**

Landing phase

Buenos Aires - Argentina

Danny

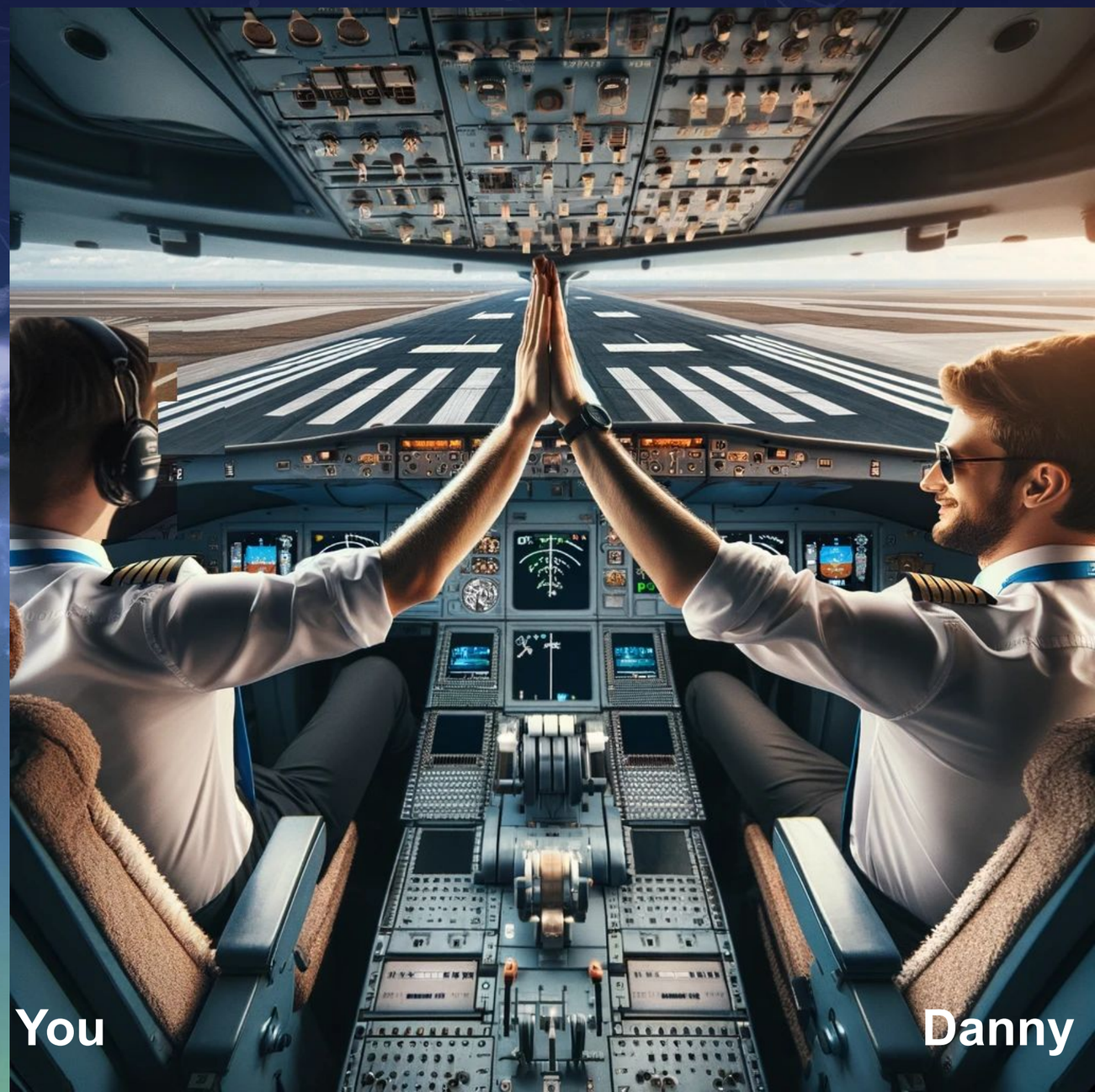
Landing phase

Buenos Aires - Argentina

Danny

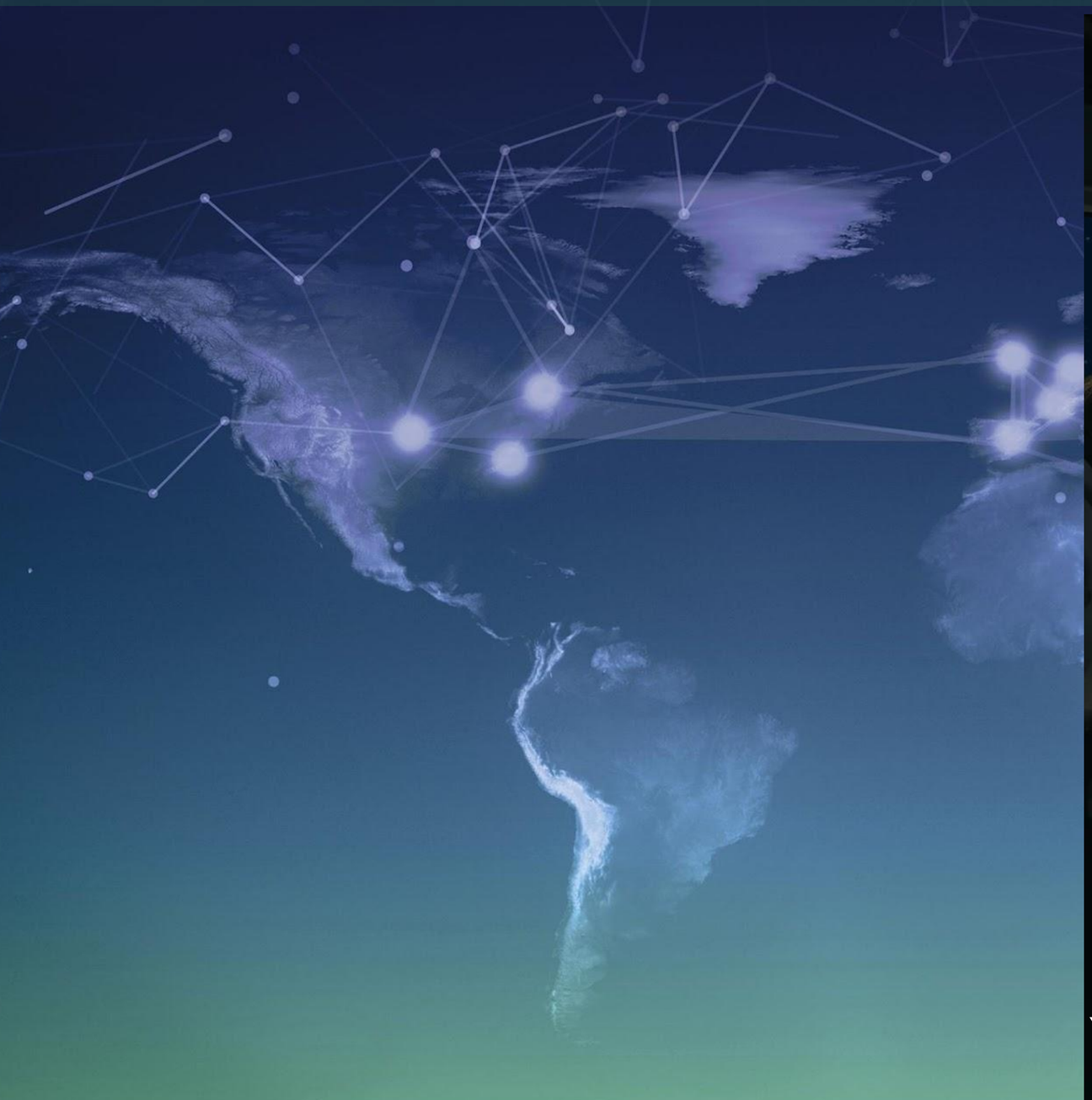
Successful landing

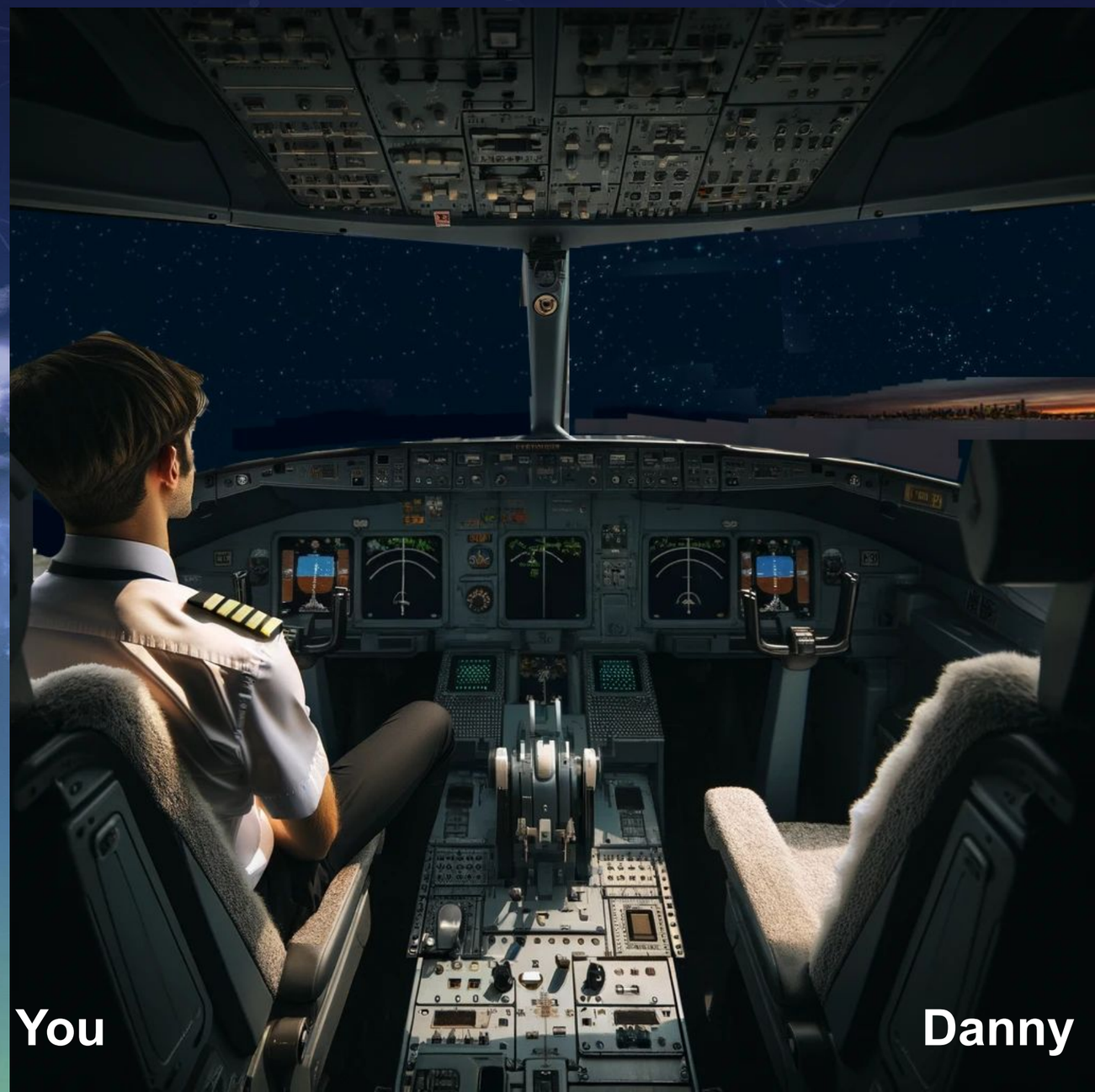
Buenos Aires - Argentina



After landing

Buenos Aires - Argentina

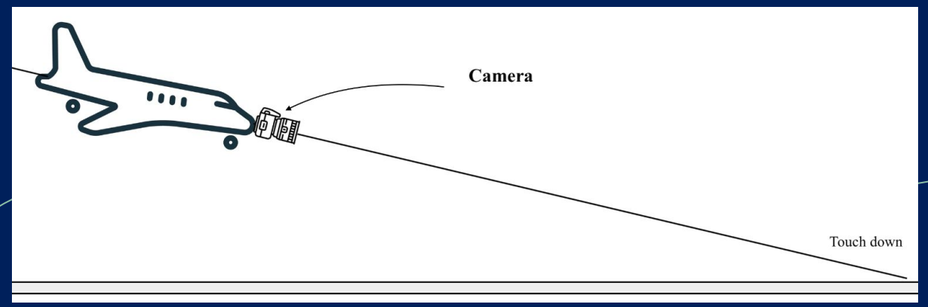


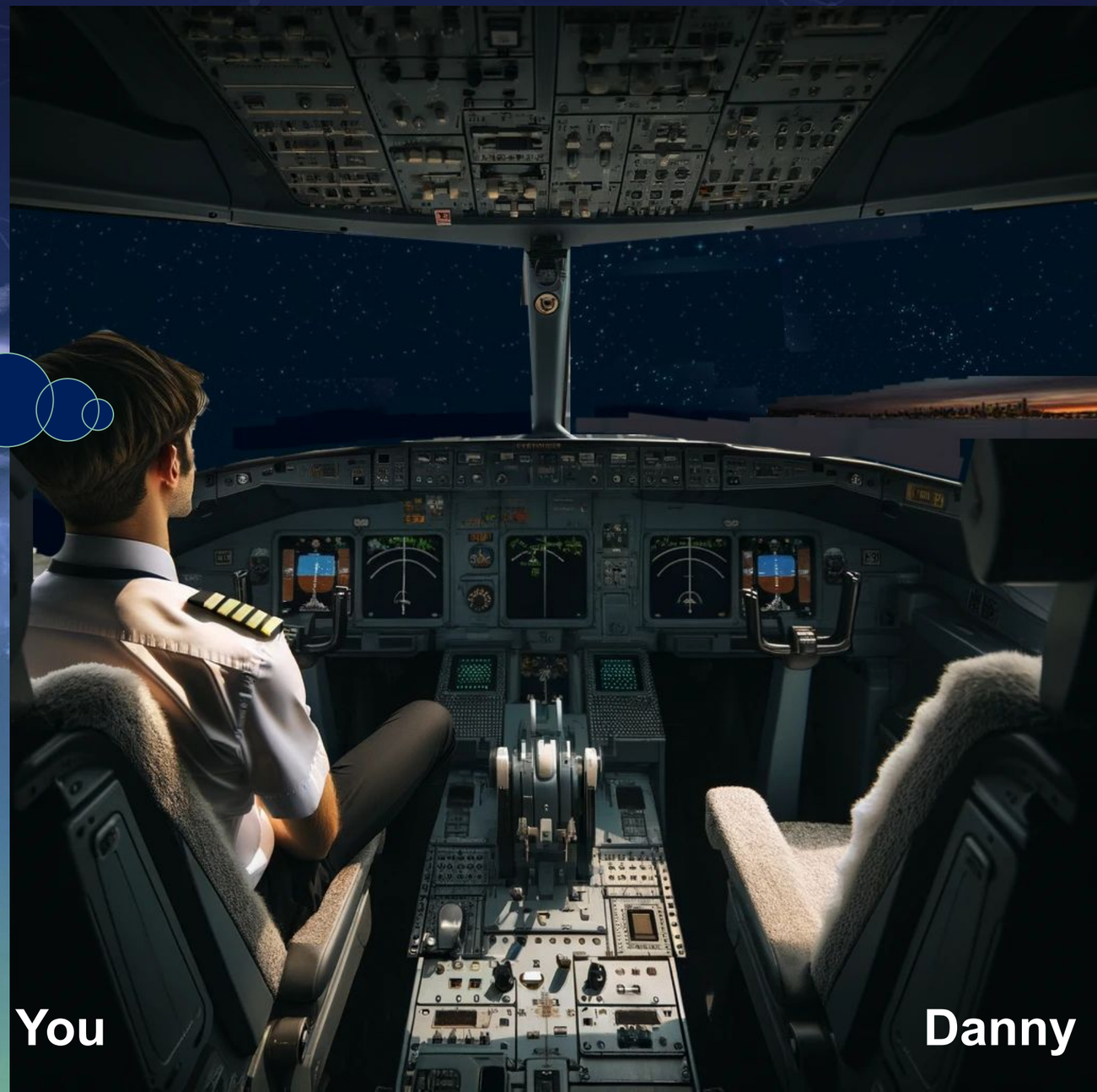


After landing

Buenos Aires - Argentina

What if we added redundant "roll" function with a camera ?





After landing

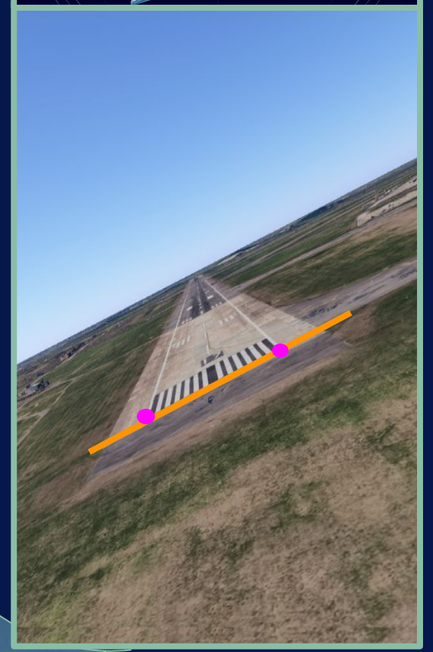
Buenos Aires - Argentina

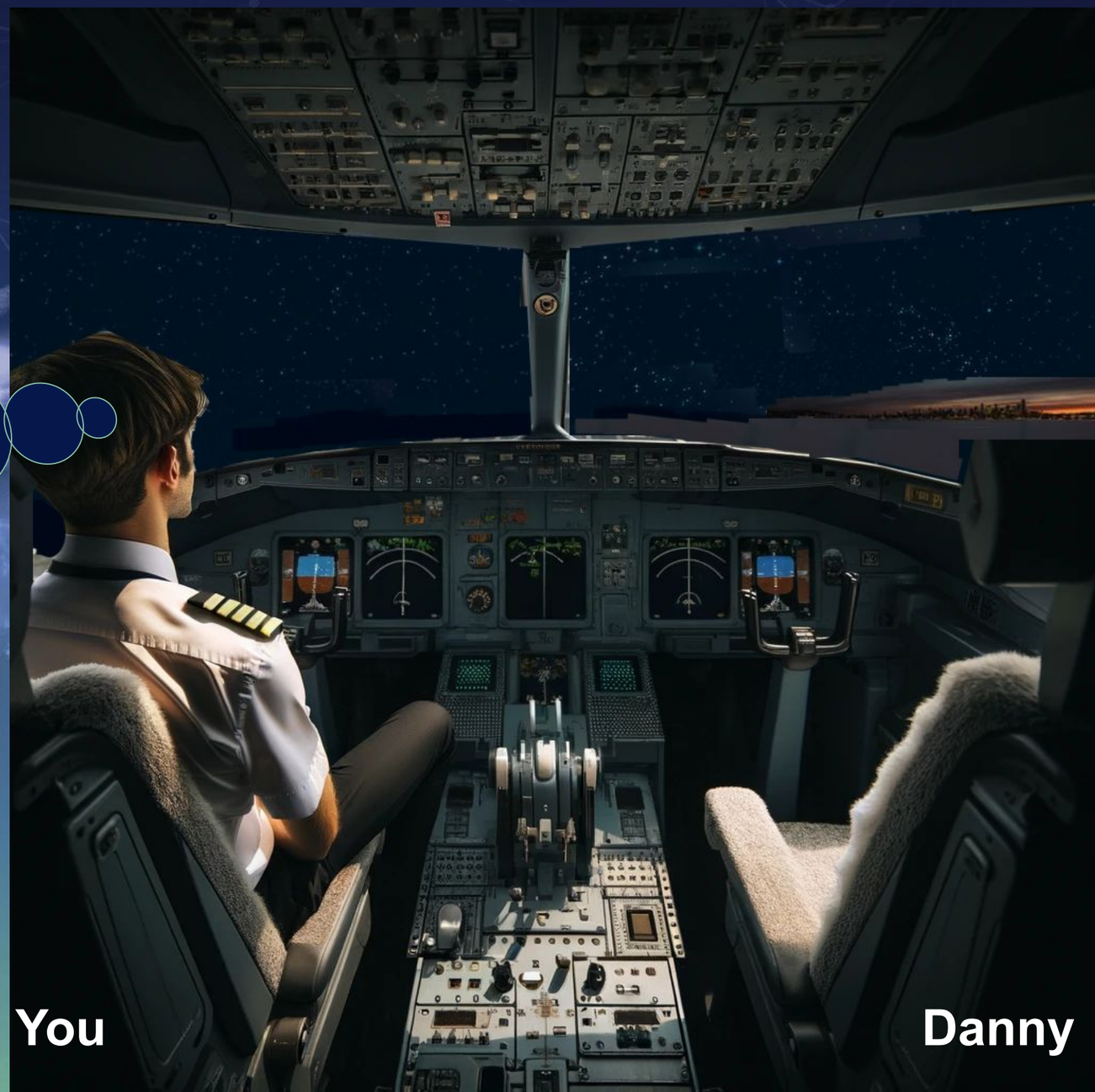
You

Danny

After landing

Buenos Aires - Argentina





After landing

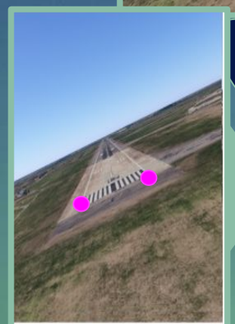
Buenos Aires - Argentina

You

Danny

After landing

Buenos Aires - Argentina



Classical algorithm

Roll

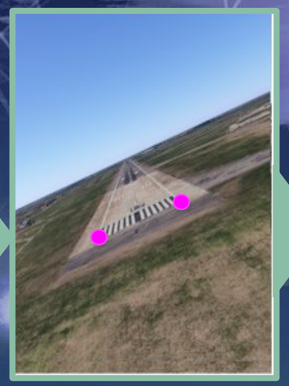
You

Danny

After landing

Buenos Aires - Argentina

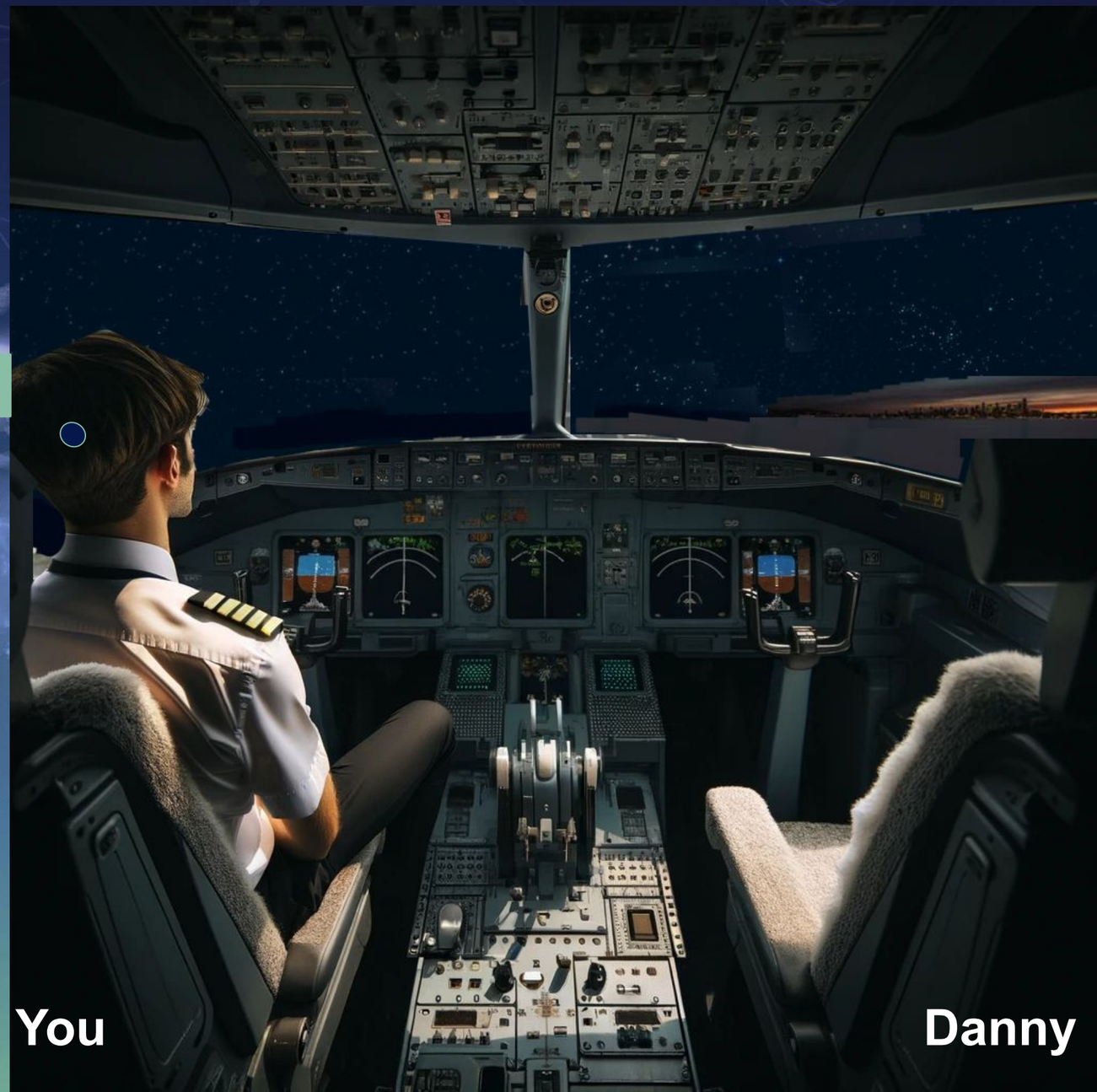
ML model



Classical algorithm

Roll

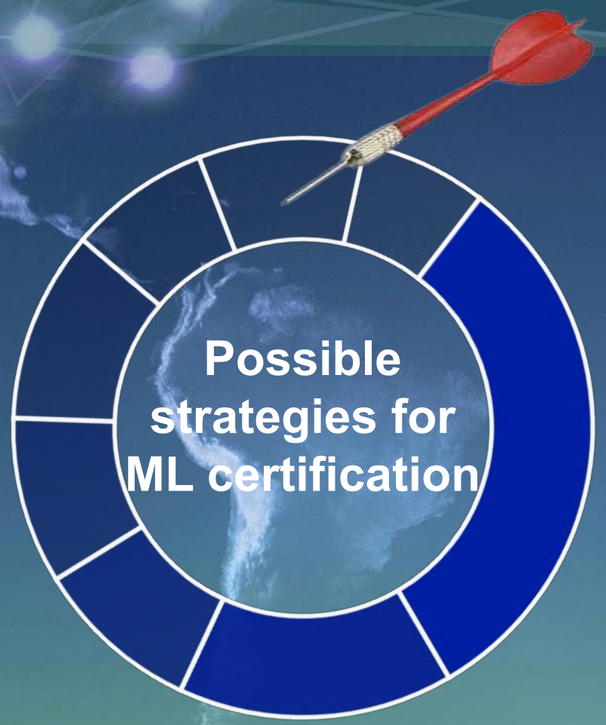
How can we certify this machine learning model?



① Context
② Subject

Subject

Subject
Formal method



1 Context

2 **Subject**

- Neural network
- Property
- Pre/Post conditions
- Formalized property
- Verification tools

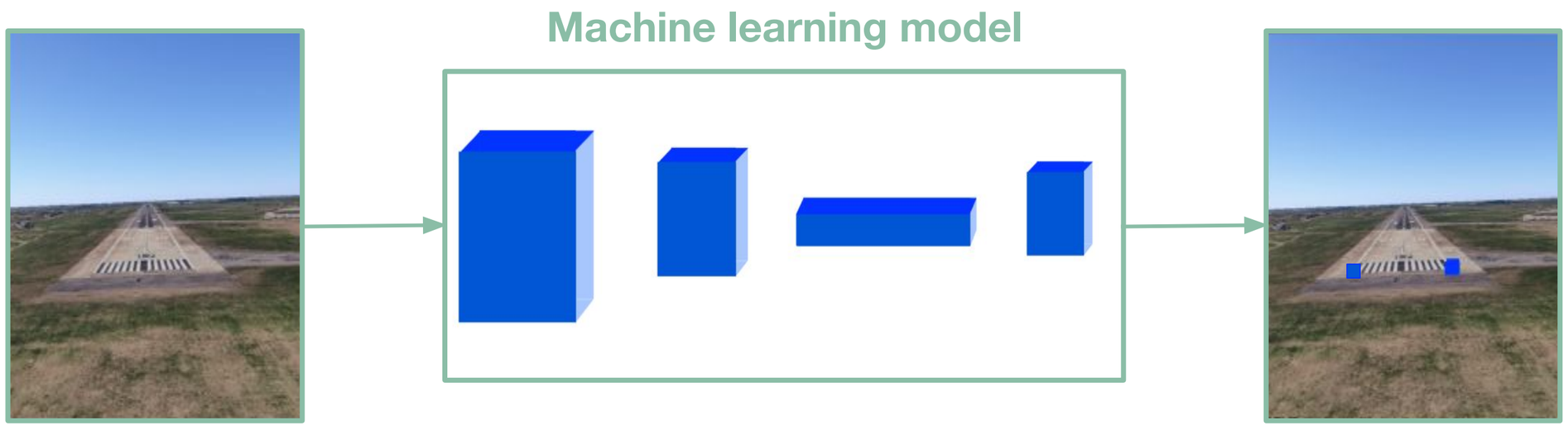
Neural network

Successive image transformations

1. Context
2. **Subject**
   - **Neural network**
   - Property
   - Pre/Post-conditions
   - Formalized property
   - Verification tools

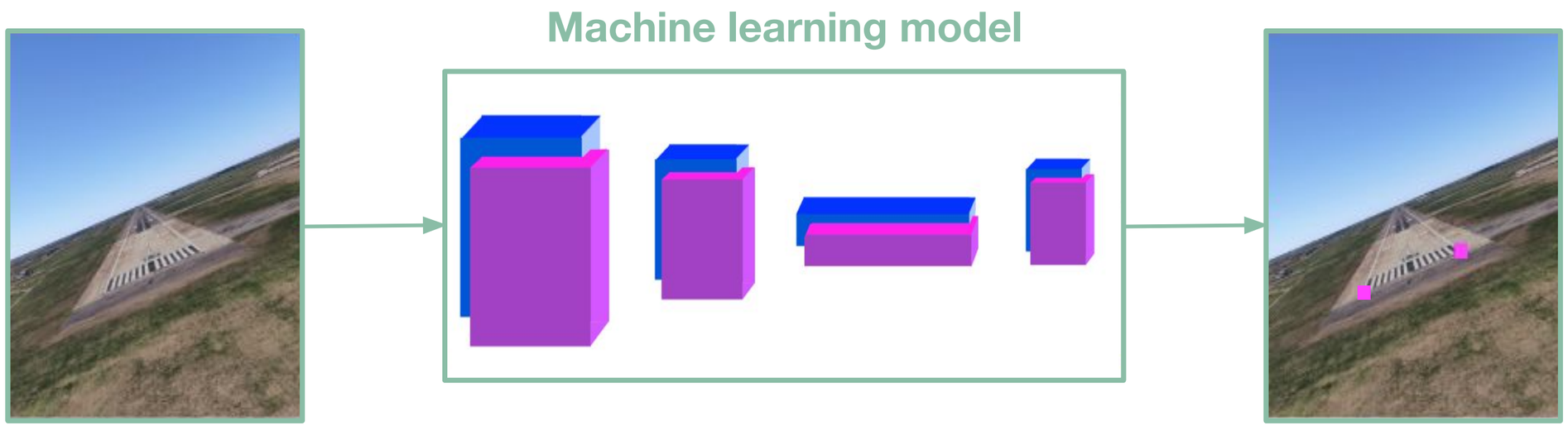
Neural network

Successive image transformations



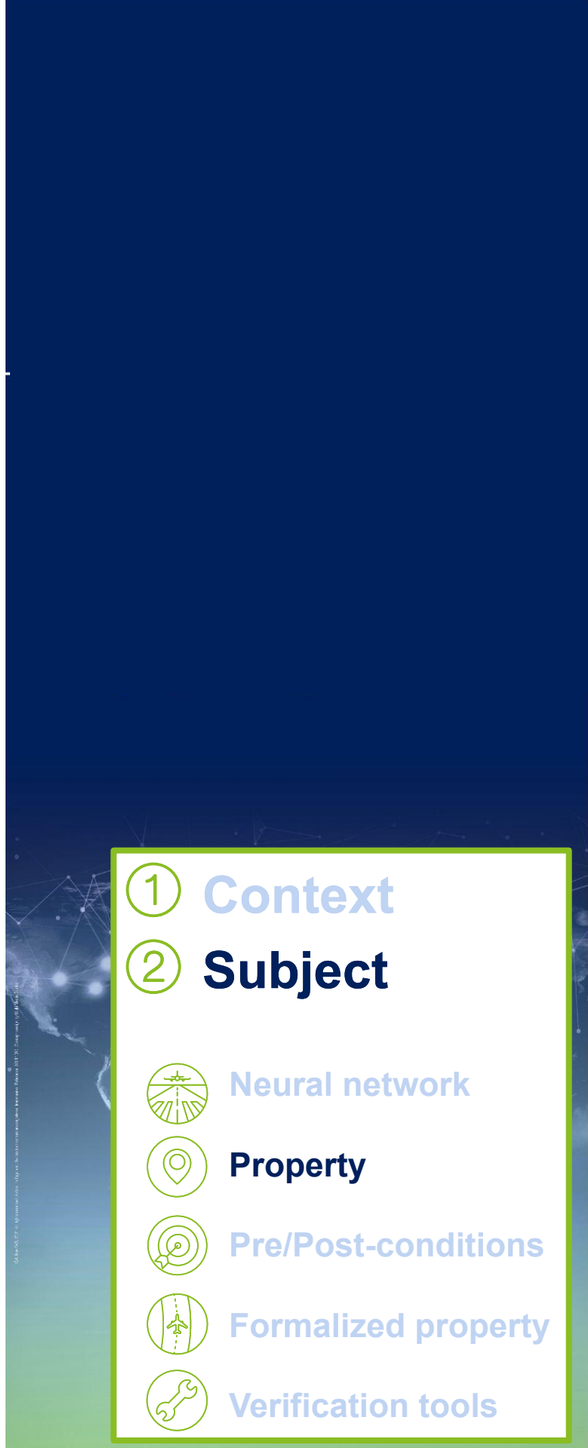
Neural network

Successive image transformations



Property

Requirement on desired model behavior

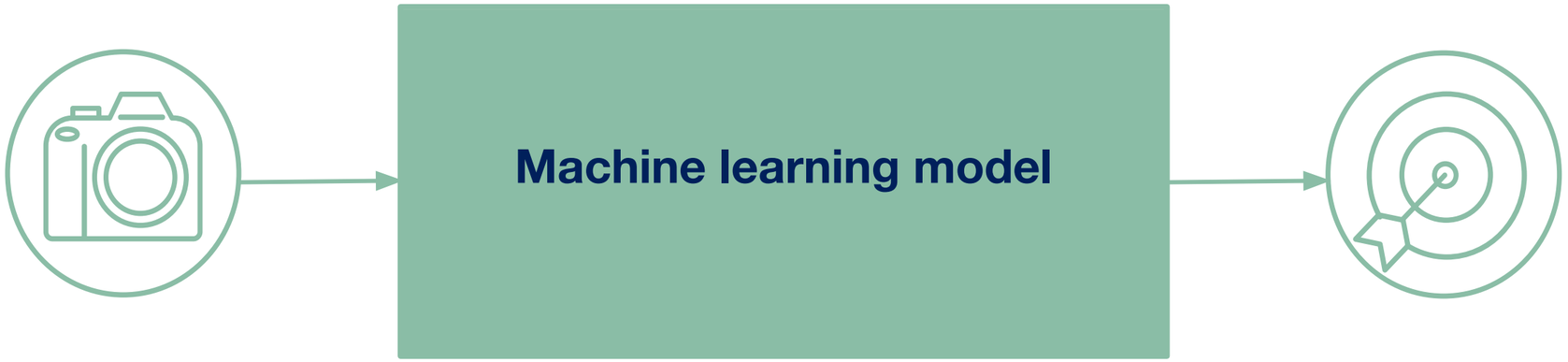


Property

Requirement on desired model behavior

Pre-condition

Post-condition



Neural network
input constraints

Neural network
output constraints

1. Context
2. **Subject**

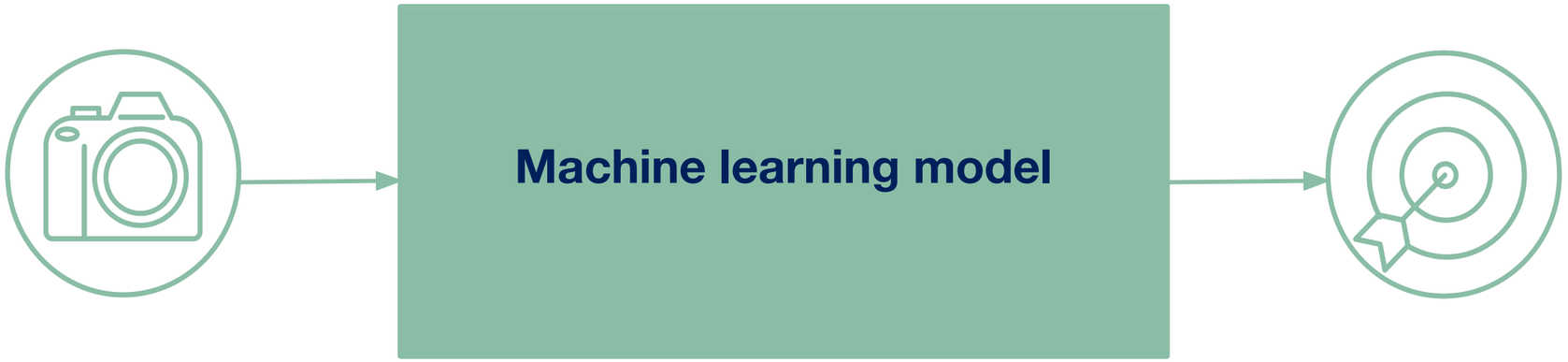
- Neural network
- **Property**
- Pre/Post-conditions
- Formalized property
- Verification tools

Property

Requirement on desired model behavior

Pre-condition

Post-condition



Neural network
input constraints

Neural network
output constraints

If the input meets the pre-condition, then,
the output meets the post-condition

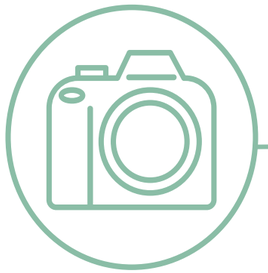
1. Context
2. **Subject**

- Neural network
- **Property**
- Pre/Post-conditions
- Formalized property
- Verification tools

Pre-conditions

Neural network input constraints

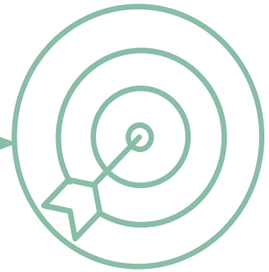
Pre-condition



Neural network input constraints

Machine learning model

Post-condition



Neural network output constraints

1. Context
2. **Subject**

- Neural network
- Property
- **Pre/Post-conditions**
- Formalized property
- Verification tools

Pre-conditions

Neural network input constraints

Machine learning model

Post-condition

Neural network
output constraints

1. Context
2. **Subject**

- Neural network
- Property
- **Pre/Post-conditions**
- Formalized property
- Verification tools

Pre-conditions

Neural network input constraints

Machine learning model

Post-condition

Neural network output constraints

Runway position

1- longitude 58.534
2- latitude 34.804
3- altitude 0 m

Aircraft position

1- longitude 58.534
2- latitude 34.807
3- altitude 25 m

Aircraft inclinaison

1- yaw 0
2- pitch 86°
3- roll 0

Environmental conditions

Weather: Sunny

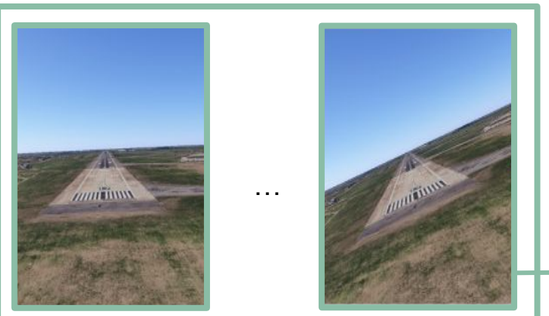
Airport: Buenos Aires
Grass
No building

1 Context
2 **Subject**

- Neural network
- Property
- **Pre/Post-conditions**
- Formalized property
- Verification tools

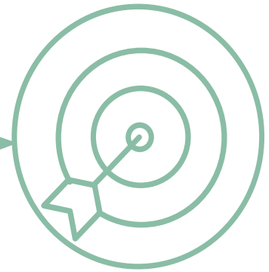
Pre-conditions

Neural network input constraints



Machine learning model

Post-condition



Neural network output constraints

Runway position

1- longitude 58.534
2- latitude 34.804
3- altitude 0 m

Aircraft position

1- longitude 58.534
2- latitude 34.807
3- altitude 25 m

Aircraft inclinaison

1- yaw 0
2- pitch 86°
3- roll ∈ [0°, 10°]

Environmental conditions

Weather: Sunny

Airport: Buenos Aires
Grass
No building

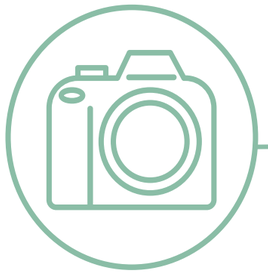
1 Context
2 **Subject**

- Neural network
- Property
- **Pre/Post-conditions**
- Formalized property
- Verification tools

Post-conditions

Desired model behavior

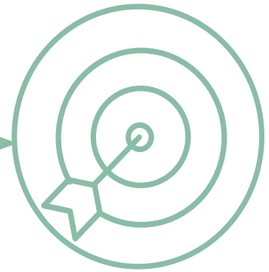
Pre-condition



Neural network
input constraints

Machine learning model

Post-condition



Neural network
output constraints

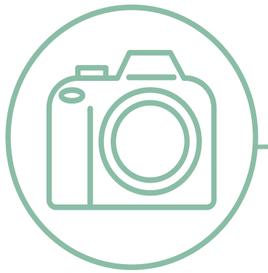
1. Context
2. **Subject**

- Neural network
- Property
- **Pre/Post-conditions**
- Formalized property
- Verification tools

Post-conditions

Desired model behavior

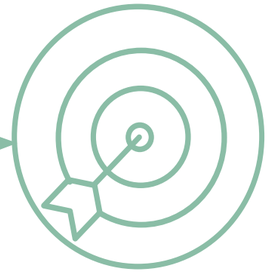
Pre-condition



Neural network
input constraints

Machine learning model

Post-condition



Neural network
output constraints

Defined by:

- Business requirements
- Technical constraints
- Performance
- …

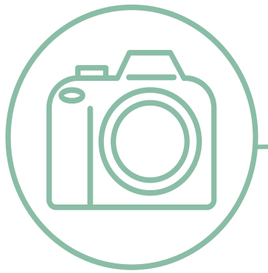
1. Context
2. **Subject**

- Neural network
- Property
- **Pre/Post-conditions**
- Formalized property
- Verification tools

Post-conditions

Desired model behavior

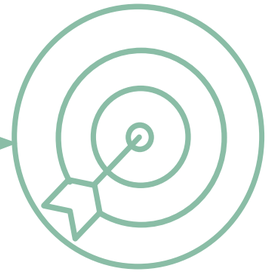
Pre-condition



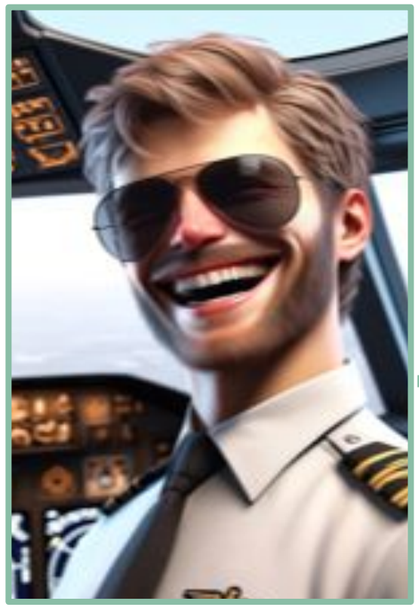
Neural network
input constraints

Machine learning model

Post-condition



Neural network
output constraints



Danny

Defined by:

- Business requirements
- Technical constraints
- Performance
- …

1. Context
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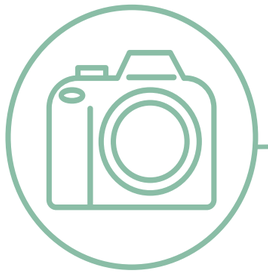
- **Pre/Post-conditions**
- Formalized property
- Verification tools

Post-conditions

Desired model behavior

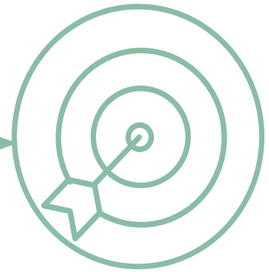
Pre-condition



Neural network
input constraints

Machine learning model

Post-condition



Neural network
output constraints

Delimited zone

1. Context
2. **Subject**

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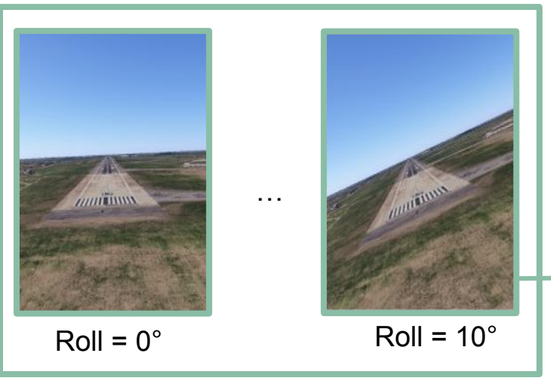
- **Pre/Post-conditions**
- Formalized property
- Verification tools

Formalized property

Mathematical traduction

Formalized property

Mathematical traduction



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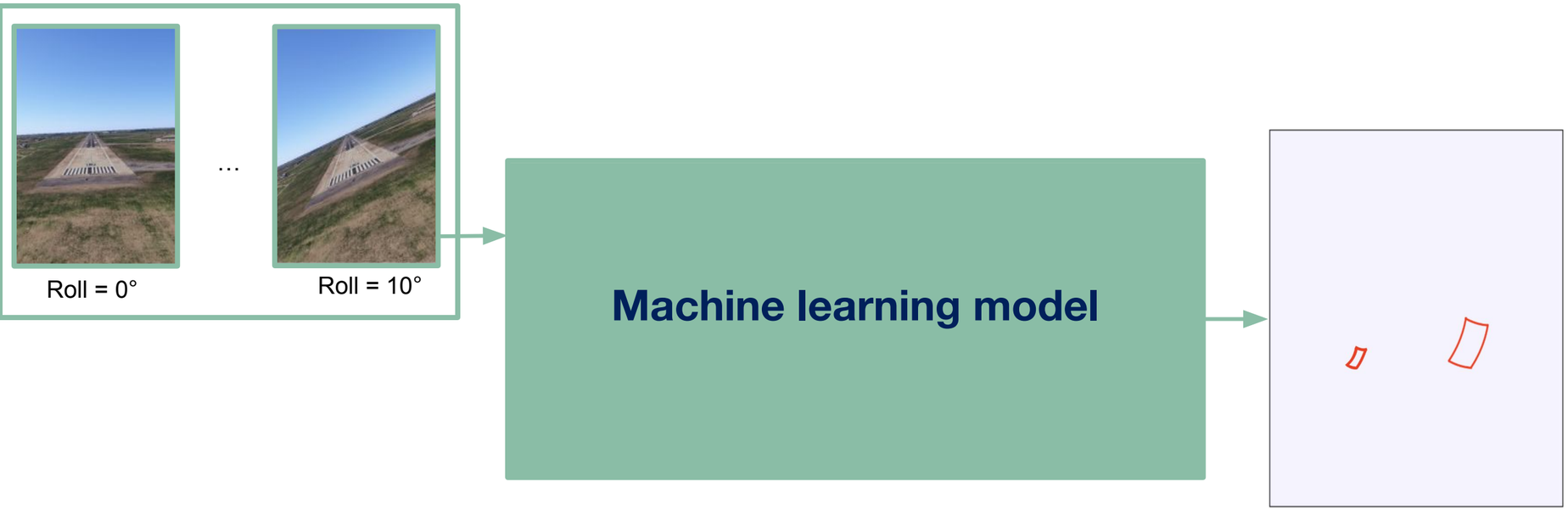
Formalized property

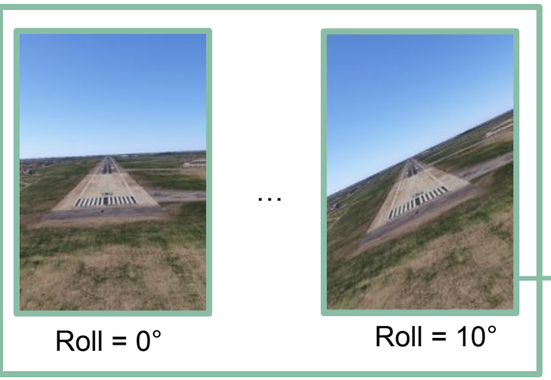
Mathematical traduction



What does it means mathematically :
“The input meets the precondition”?

Formalized property

Mathematical traduction

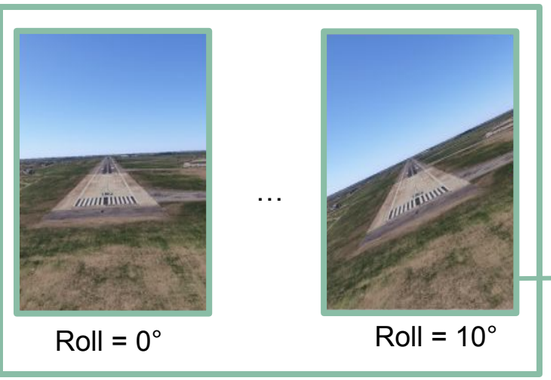


1	2	3
4	5	6
7	8	9

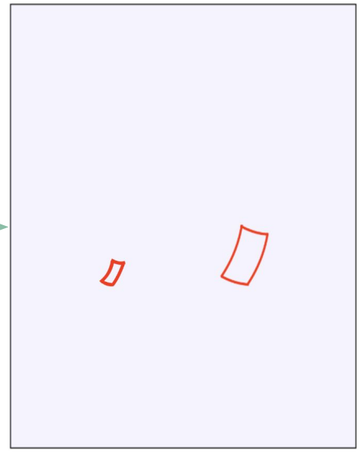
9 pixels image

Formalized property

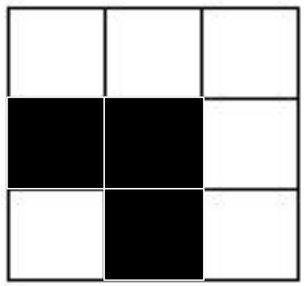
Mathematical traduction



Machine learning model



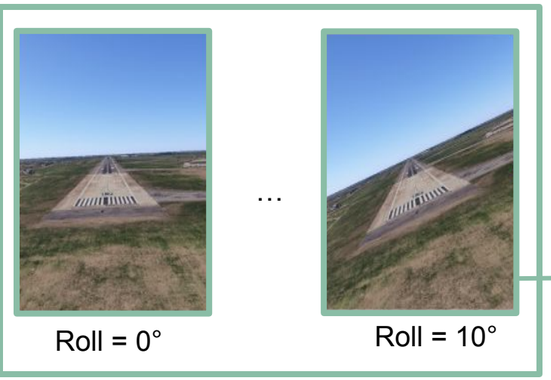
1	2	3
4	5	6
7	8	9



example

Formalized property

Mathematical traduction



1	2	3
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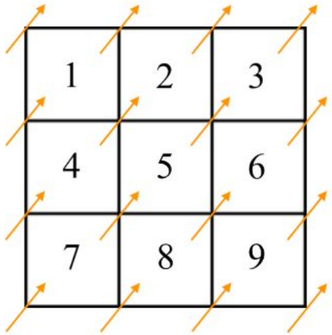
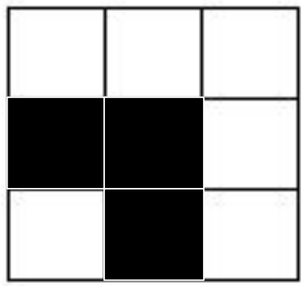




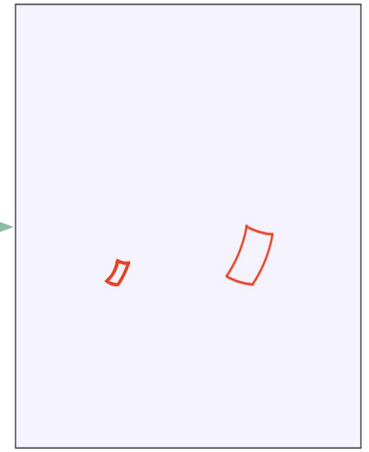
example

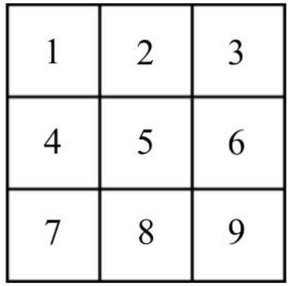
1. Context
2. **Subject**
   - Neural network
   - Property
   - Pre/Post-conditions
   - **Formalized property**
   - Verification tools

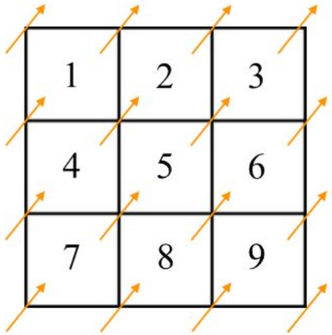
Formalized property

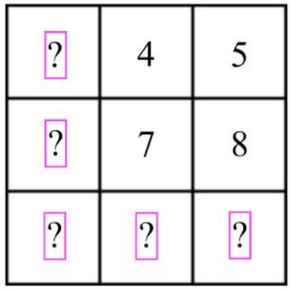
Mathematical traduction

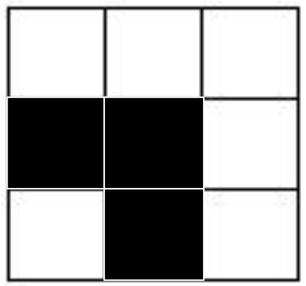
Machine learning model



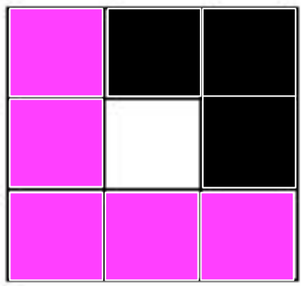








example

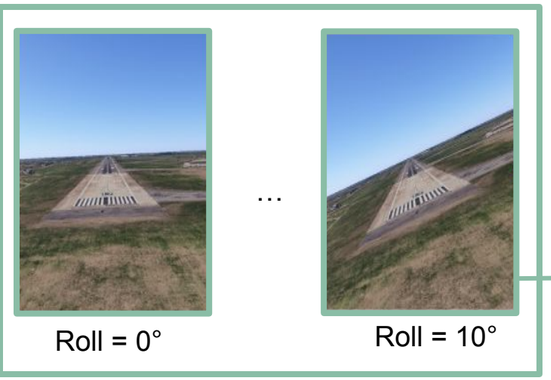


example

1. Context
2. **Subject**
   - Neural network
   - Property
   - Pre/Post-conditions
   - **Formalized property**
   - Verification tools

Formalized property

Mathematical traduction



1	2	3
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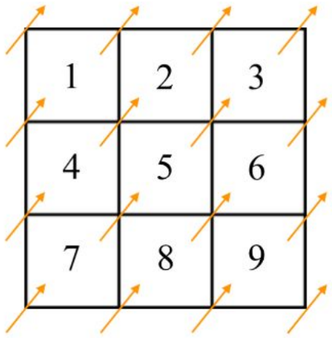


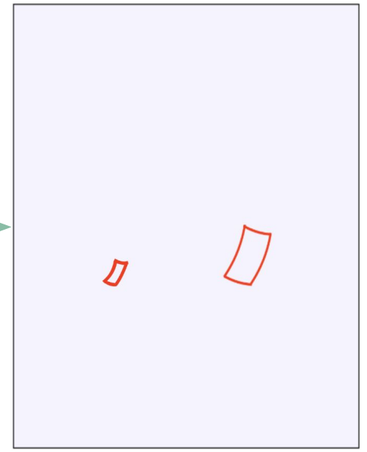
?	4	5
?	7	8
?	?	?

5 pixels unknown in black and white

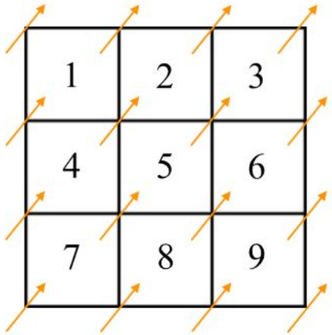
Formalized property

Mathematical traduction

Machine learning model

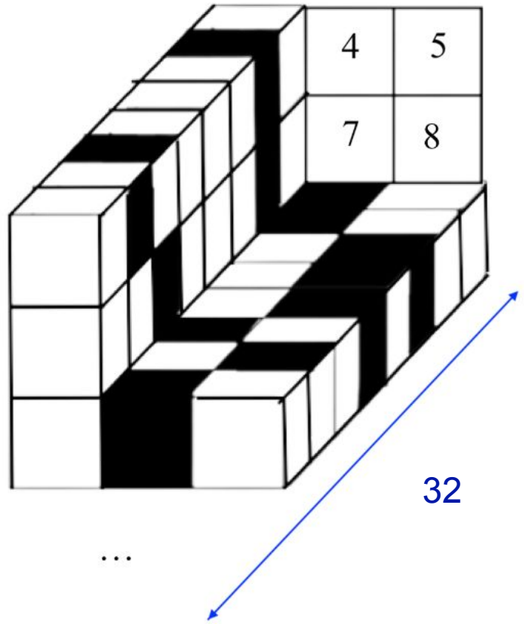


1	2	3
4	5	6
7	8	9



?	4	5
?	7	8
?	?	?

5 pixels unknown in black and white
32 combinations

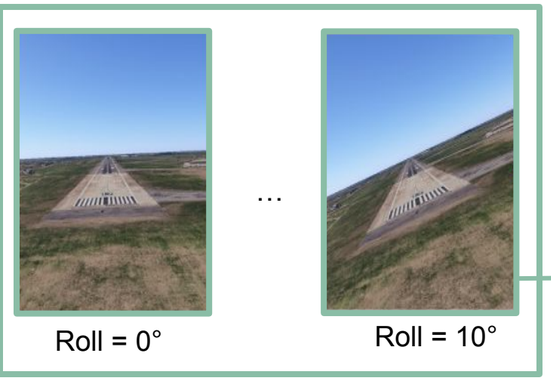


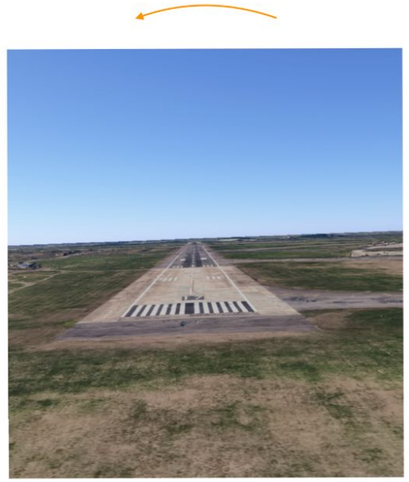
1. Context
2. **Subject**

- Neural network
- Property
- Pre/Post-conditions
- **Formalized property**
- Verification tools

Formalized property

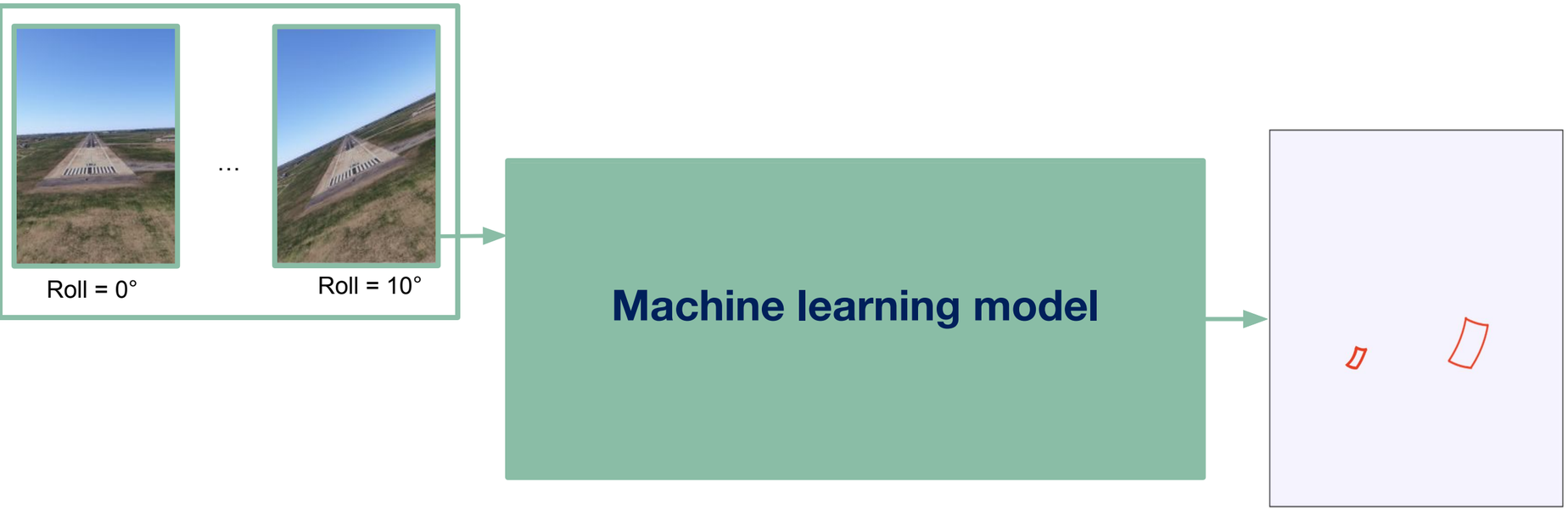
Mathematical traduction

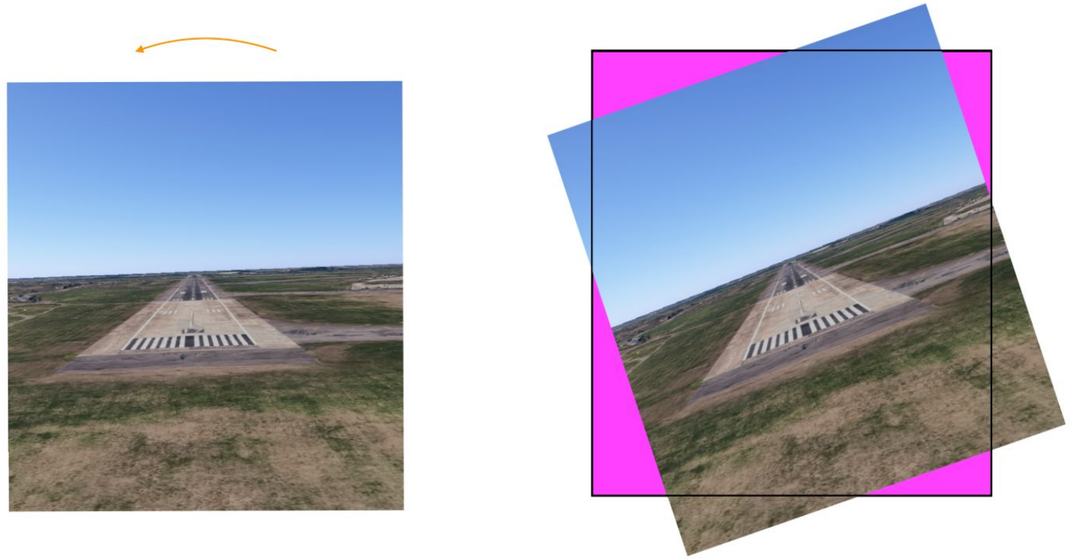




Formalized property

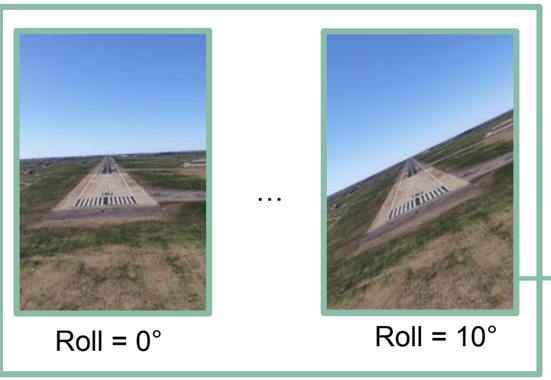
Mathematical traduction



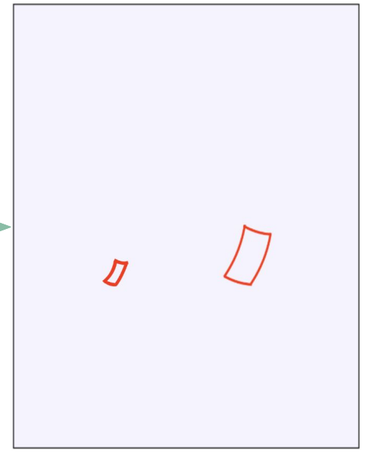


Formalized property

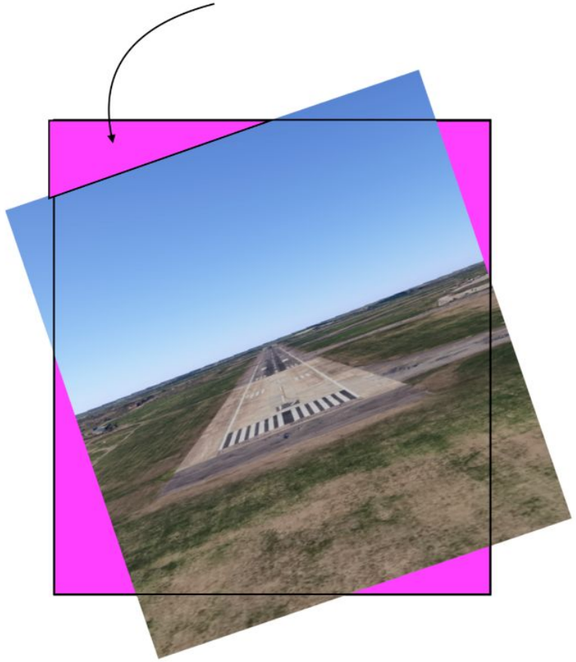
Mathematical traduction



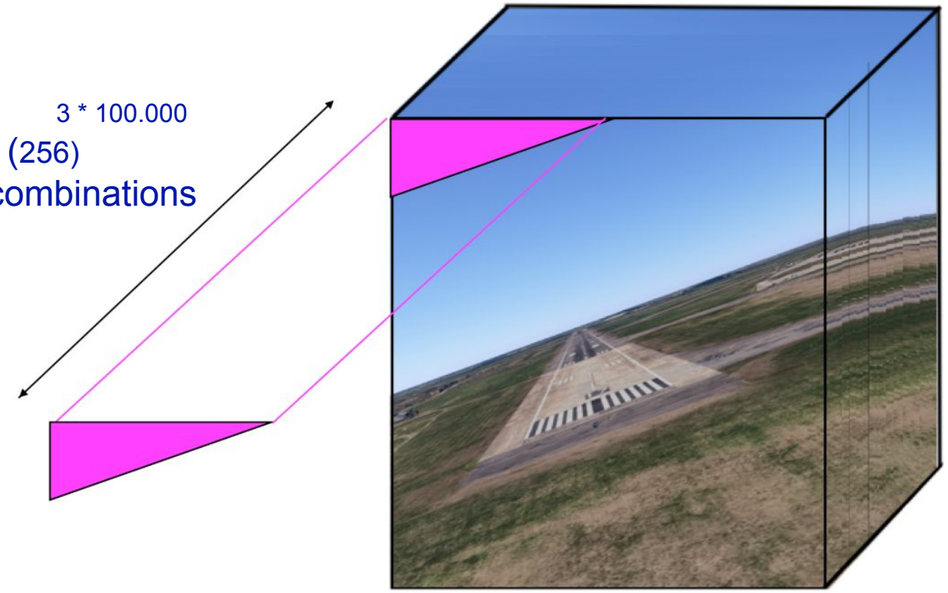
Machine learning model



100.000 unknown pixels in RGB

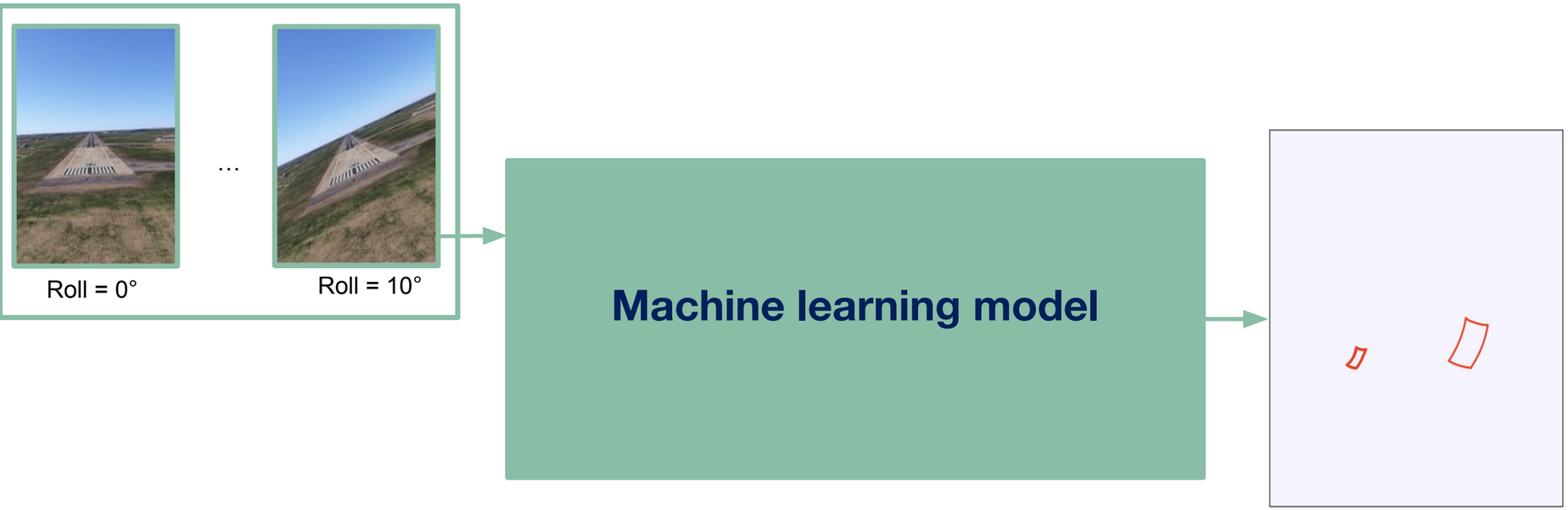


3 * 100.000
> (256)
combinations



Formalized property

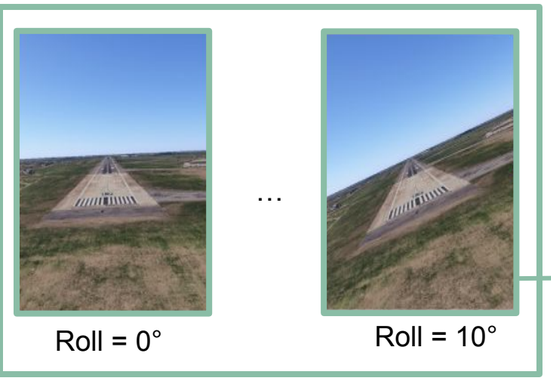
Mathematical traduction

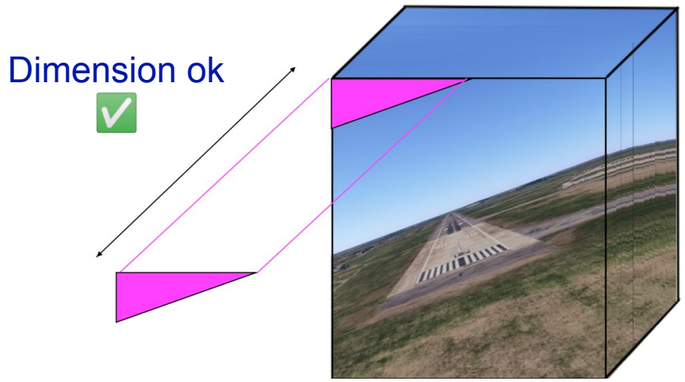


Find strategies to reduce dimensionality

Formalized property

Mathematical traduction

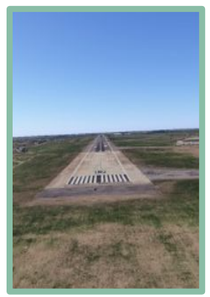




Find strategies to reduce dimensionality

Formalized property

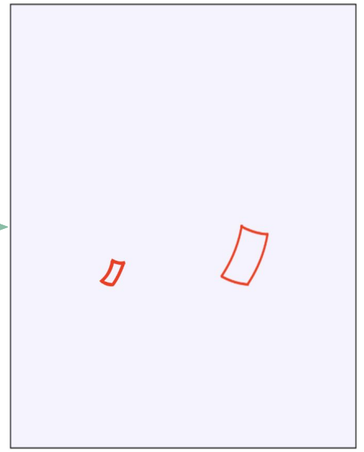
Mathematical traduction

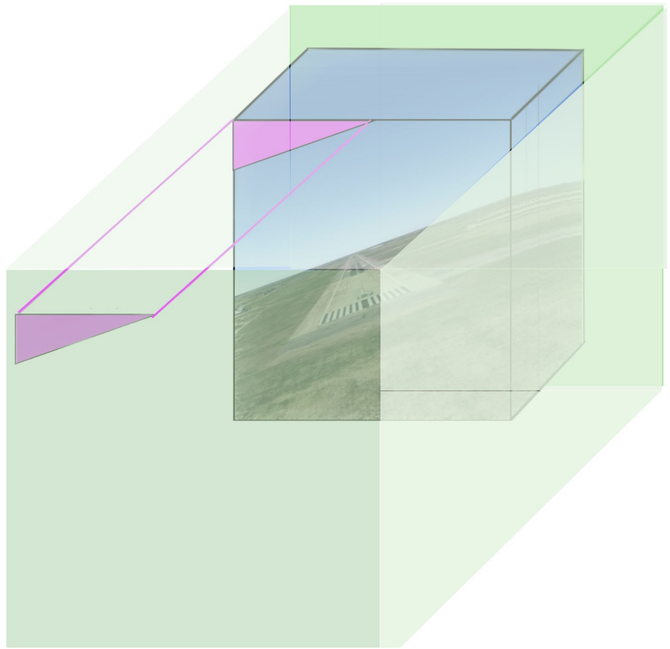


Roll = 0°

Roll = 10°

Machine learning model





Creating simplified representation that encompasses all possible cases

abstraction

1. Context
2. **Subject**

- Neural network
- Property
- Pre/Post-conditions
- **Formalized property**
- Verification tools

Verification tools

Automated validation software

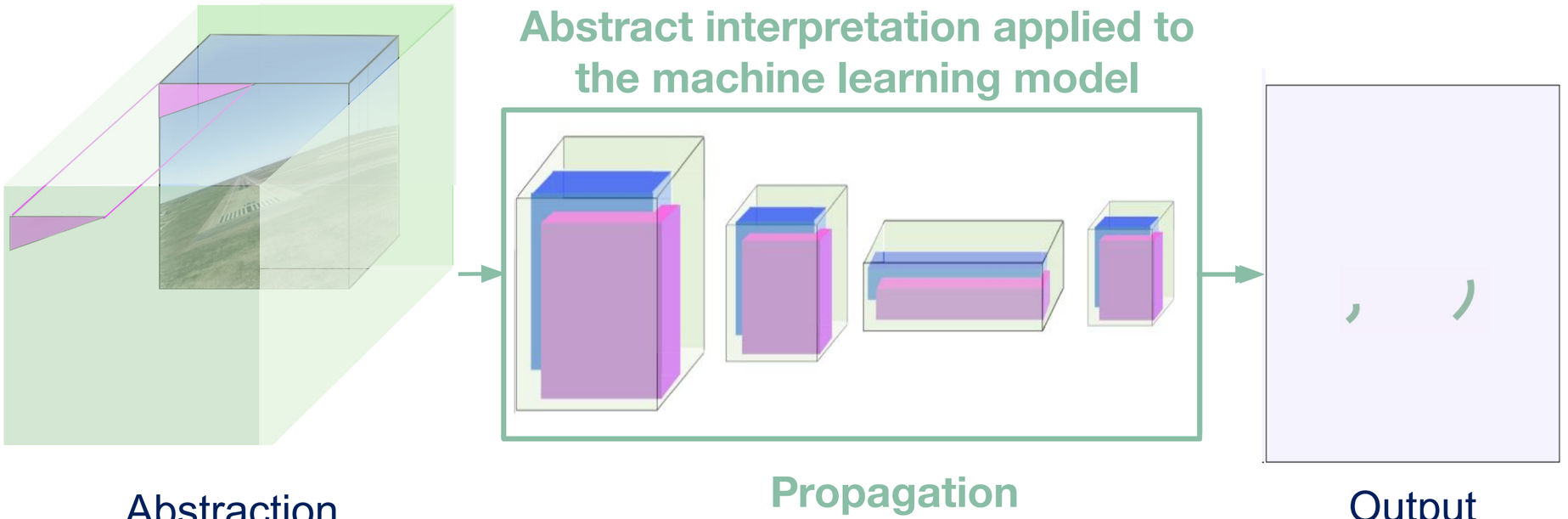
1 Context

2 **Subject**

- Neural network
- Property
- Pre/Post-conditions
- Formalized property
- **Verification tools**

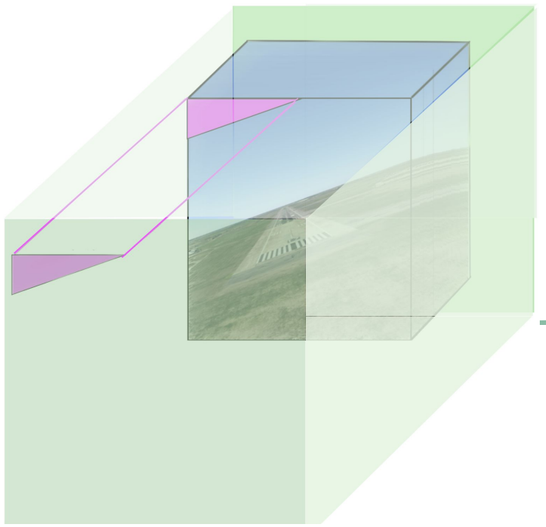
Verification tools

Automated validation software



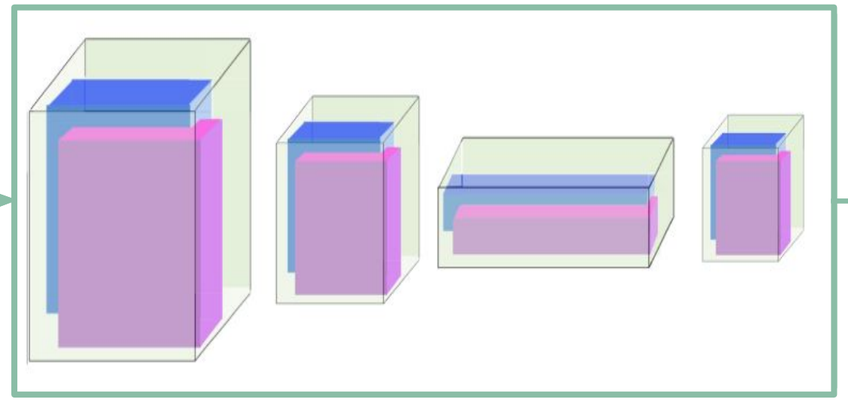
Verification tools

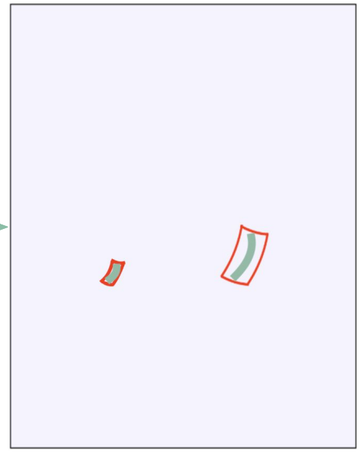
Automated validation software



Abstraction

Abstraction interpretation applied to the machine learning model





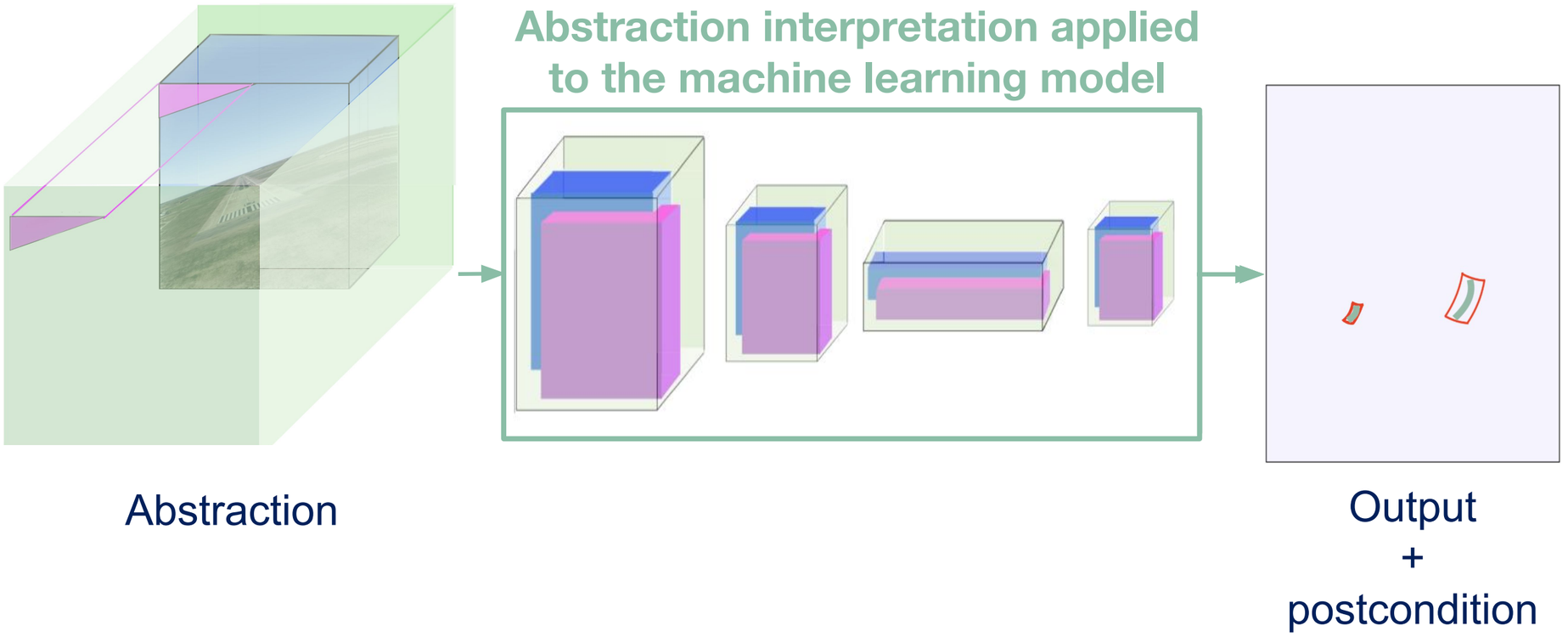
Output
+
postcondition

1. Context
2. **Subject**

- Neural network
- Property
- Pre/Post-conditions
- Formalized property
- **Verification tools**

Verification tools

Automated validation software



Abstraction

Output
+
postcondition

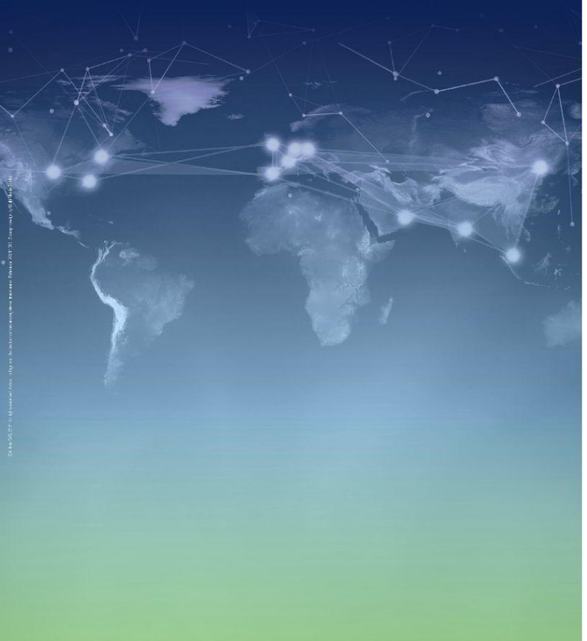
The postcondition is verified for the abstraction

Verified property

1. Context
2. **Subject**

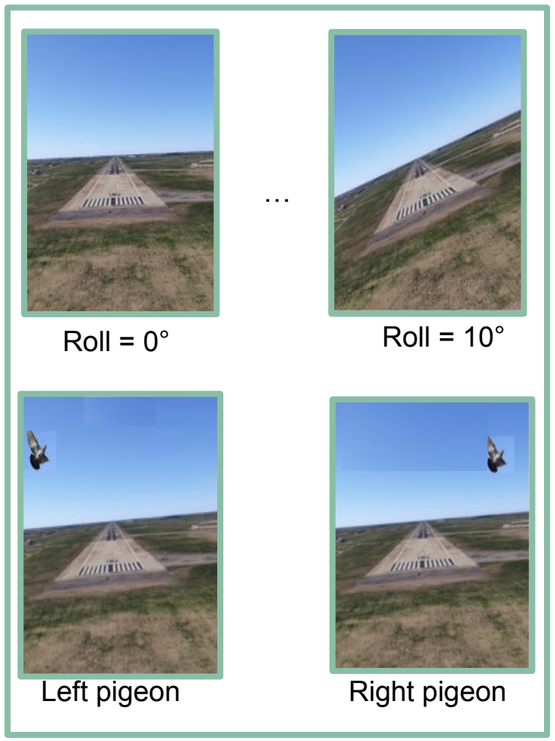
- Neural network
- Property
- Pre/Post-conditions
- Formalized property
- **Verification tools**

STAKES
OF THE SUBJECT



STAKES
OF THE SUBJECT

1 Not only is the roll set

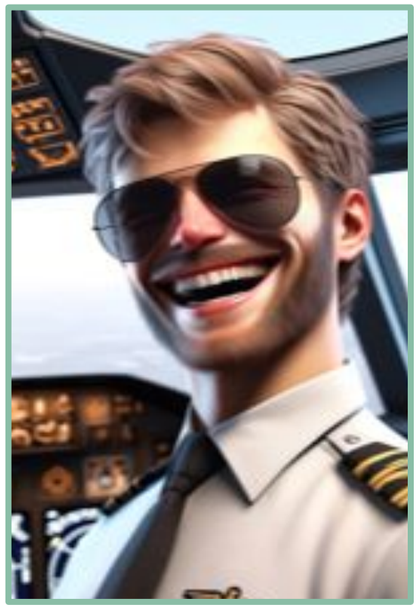


AIRBUS

STAKES
OF THE SUBJECT

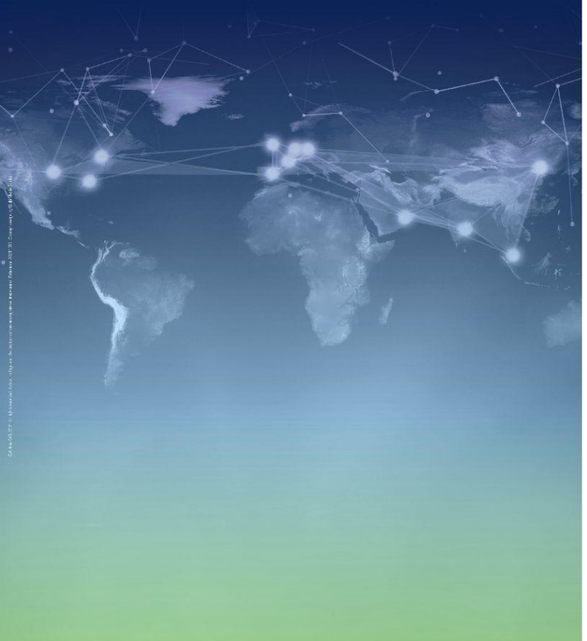
1. **Not only is the roll set**

2. **Find properties**



Danny

STAKES
OF THE SUBJECT



1. **Not only is the roll set**
2. **Find properties**
3. **Abstraction**

STAKES
OF THE SUBJECT

1. **Not only is the roll set**
2. **Find properties**
3. **Abstraction**
4. **Abstract interpretation :**
   - **Use tools - Use case : Object detection**
   - **Scalability issue**

Thank you for your attention

Noémie Cohen

Supervisor:

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Christophe Gabreau, Mélanie Ducoffe AIRBUS

ANITI

ONERA
THE FRENCH AEROSPACE LAB

AIRBUS