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## **Implementing Blockchain Technology in NMAC system**

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# Introduction



- **Motivation**

- Emerging technologies have focused on blockchain technologies.
- Review of possible applications in the nuclear industries.

- **Objectives**

- Ensure transparency transactions in control of nuclear and radioactive material movements.

- **Contribution**

-  The implementation of the NMAC system using blockchain.

# Introduction



## Art of State

- Cryptocurrencies
- Energy distribution from smart grids
- Finances and property rights
- Organizations such as DARPA (United State) or Rosatom (Russia) invest in R&D on blockchain to safeguard military assets and in nuclear energy respectively.

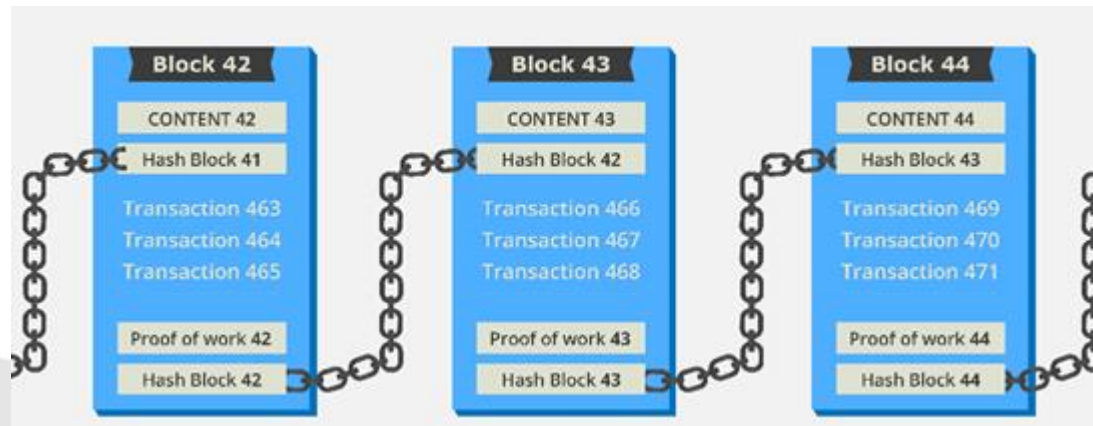


# Blockchain



- **Blockchain characteristics**

- Blockchain constructs a chronological chain of blocks, hence the name "block-chain".
- Each block is an immutable information unit.
- Blockchain consists of timestamping of transactions, Peer-to-Peer networks, cryptography, and shared computational power.
- Components: data model, transaction language, consensus algorithm.
- Smart Contracts: automatic execution code.



# Use case: NMAC System

## Scenario

“A new set of fuel rods arrives to the facility. A custodian named John Muller receives the set of material.

He must login in a web page that allows him to specify the type of source transaction. In this case, the transaction is record new sources.

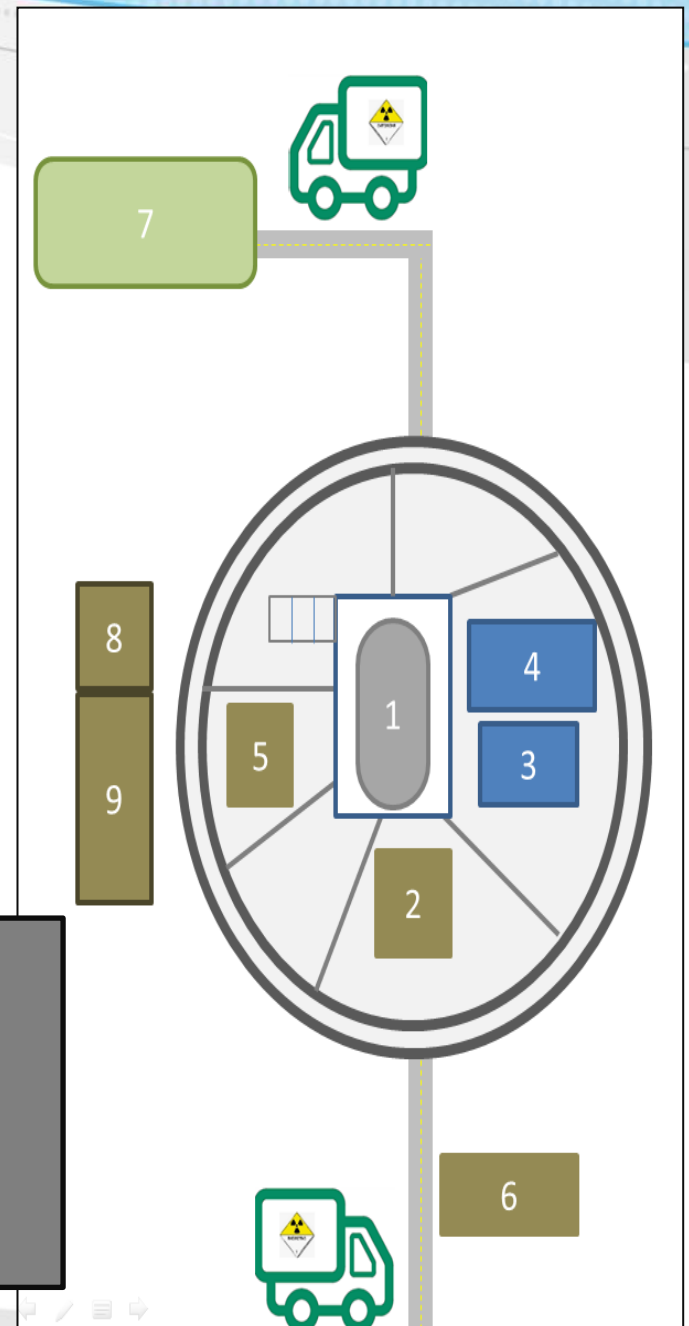
These transactions are registered in the nmac-blockchain with a timestamp specification.

Then, at the moment when the fuel rod replacement occurs, Muller has to write this new transaction in the nmac-blockchain.”

### Movements:

- ✓ Shipment
- ✓ Receipt
- ✓ Transfer
- ✓ Relocation

1. Nuclear Reactor Core
2. Storage Enclosure
3. Maneuvering Pool
4. Waste Disposal Pool
5. Laboratory 1
6. Reception
7. Waste Disposal Facility
8. Enclosure 1
9. Enclosure 2



# Use case: NMAC System



## Constrains by design

- Separation of duties should be maintained to ensure that the same person cannot both transfer and receive the nuclear material.
- Radiation should be measured before and after each movement: the present architecture eludes that verification.





# NMAC System: Design



## Participants

- **Regulator**: Monitoring source movements, audit the blockchain.
- **Nuclear Material Custodian**: Source/Nuclear Material Check in, Source/Nuclear Material Check out, Relocation of nuclear source, Adding source to the blockchain and Adding new location.



## Assets

- **Nuclear Material**

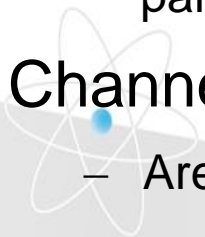


## Transactions

- 1) Add sources, 2) return a list of sources, 3) request information about a particular source, and 4) modify the source's custodian.

## Channels

- Are the communication buses between participants.



# NMAC System: Design



A block structure in the nmac-blockchain

BLOQUE
<u>Timestamp</u>
Hash anterior
<u>ID_Material</u>
<u>ID_Responsable</u>
Ubicación geográfica del material
Estado del material
Peso del material
<u>Nonce</u>



Custodio 1

BLOQUE
<u>Timestamp</u>
Hash anterior
<u>ID_Material</u>
<u>ID_Responsable</u>
Ubicación geográfica del material
Estado del material
Peso del material
<u>Nonce</u>



Custodio 2

BLOQUE
<i>Timestamp</i>
Hash anterior
ID_Material
ID_Responsable
Ubicación geográfica del material
Estado del material
Peso del material
<i>Nonce</i>



Regulador ARN



Custodio 3



Verificador  
Secretaría de  
Energía

BLOQUE
<u>Timestamp</u>
Hash anterior
<u>ID_Material</u>
<u>ID_Responsable</u>
Ubicación geográfica del material
Estado del material
Peso del material

BLOQUE
<u>Timestamp</u>
Hash anterior
<u>ID_Material</u>
<u>ID_Responsable</u>
Ubicación geográfica del material
Estado del material
Peso del material
<u>Nonce</u>

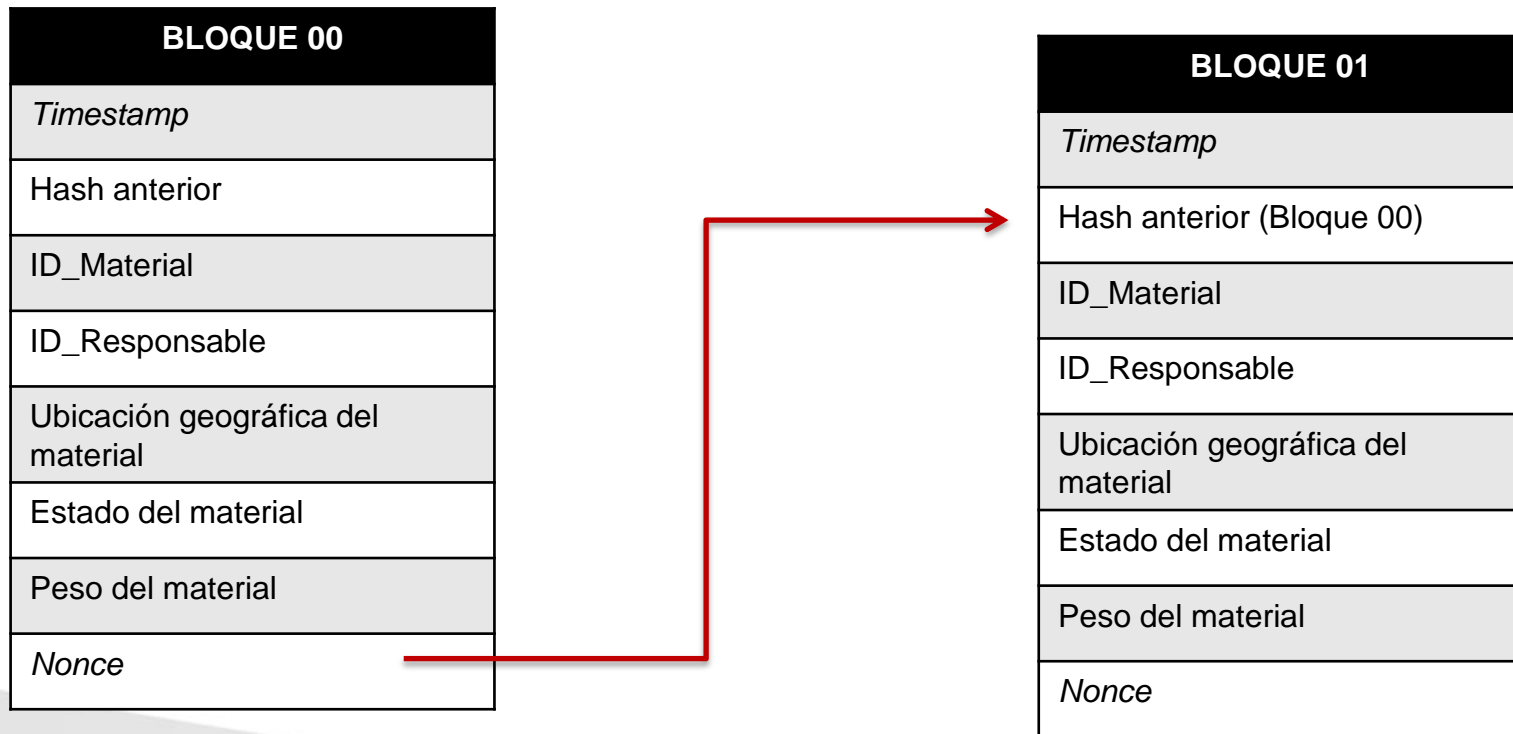
BLOQUE
<u>Timestamp</u>
Hash anterior
<u>ID_Material</u>
<u>ID_Responsable</u>
Ubicación geográfica del material
Estado del material
Peso del material
<u>Nonce</u>



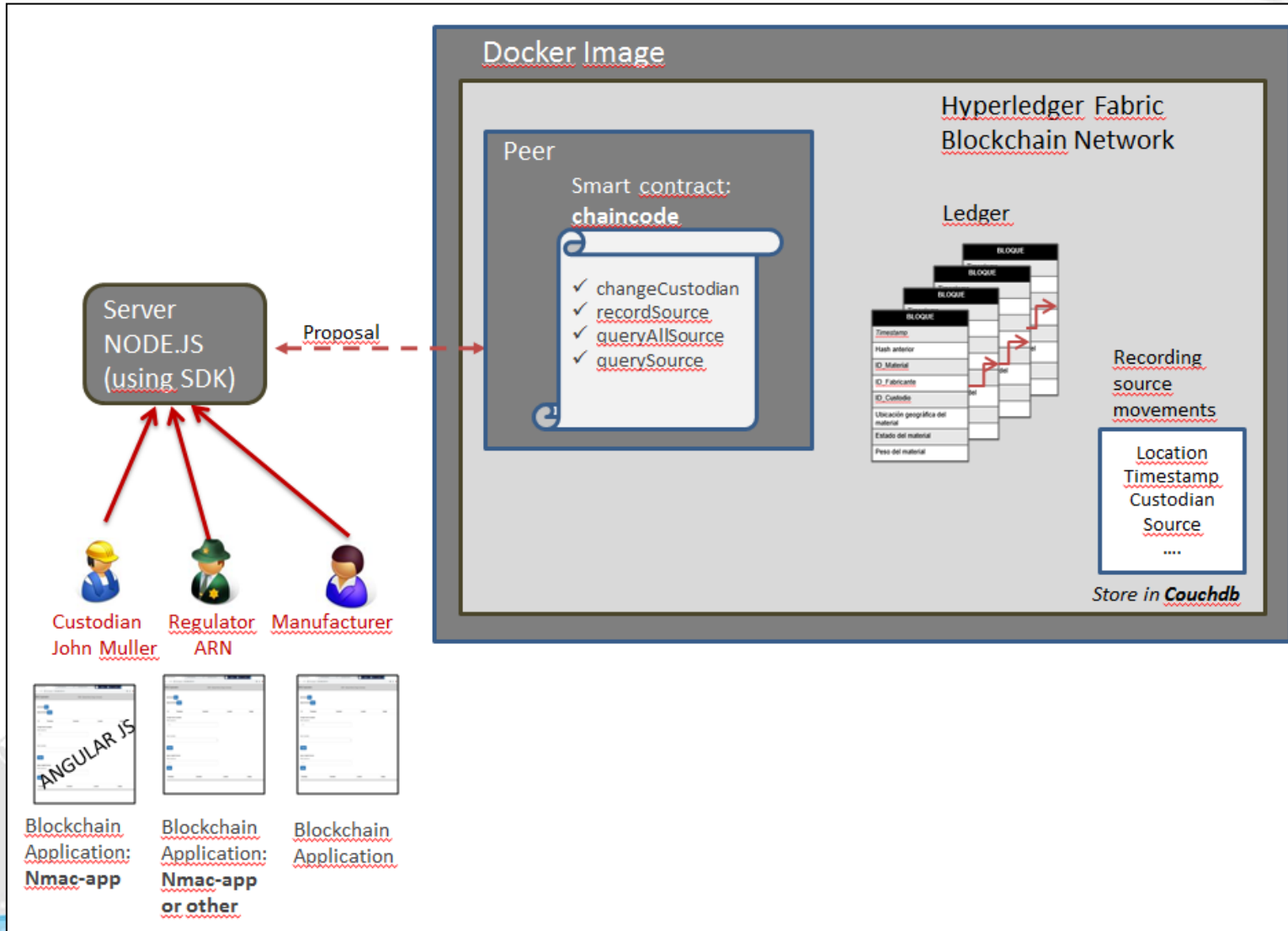
# NMAC System: Design



Representation of a previous hash.



# NMAC Blockchain Architecture



# NMAC Blockchain: Proof of Concepts



CoachDB

The screenshot shows a web browser window with the address bar displaying `192.168.60.229:5984/_utils/#database/mychannel_nmac-app/1`. The page title is `mychannel_nmac-app > 1`. A sidebar on the left contains various navigation icons. The main content area displays a JSON document with the following fields:

```
1 {  
2   "_id": "1",  
3   "_rev": "1-1d383023125001a1f1efd19495a5f892",  
4   "custodian": "Miriam",  
5   "isotope": "U235",  
6   "location": "Core Reactor",  
7   "timestamp": "1504054225",  
8   "~version": "\u0000CgHBAgA="
```

# NMAC Blockchain: Proof of Concepts



## Nmac-app

Browser window showing the NMAC Application interface. The address bar displays "192.168.60.229:8000". The page title is "NMAC Application" and the subtitle is "CNEA - National Atomic Energy Commission".

Buttons: "Add Source" (with a "New" sub-button) and "Query All Source" (with a "Query" sub-button).

ID	Timestamp	Custodian	Location	Isotope
1	1504054225	Miriam	SNM safe	U235
2	1504057825	Dave	Aries Lab	PuMT51
3	8754987634	Diego	Enclousure 2	U235
4	1496105425	Amalea	Source Safe	MOXe
5	1493512301			
6	1494117101			
7	1496104301			
8	1485066691			
9	1485153091			
10	1487745091			
11	5656565656			

Close-up of the "Change Source Custodian" form. A table shows source details with "Emily Tylor" highlighted in a red box.

55	1574432784714	Emily Tylor	Core Reactor	U235
6767	1574432253406	Susan Wilson	Waste Disposal Pool	U235

**Change Source Custodian**  
**Success!**

Enter a source id:

Select custodian:

**Change Source Custodian**  
Enter a source id:

55	1574432784714	John Muller	Core Reactor	U235
6767	1574432253406	Susan Wilson	Waste Disposal Pool	U235



# NMAC Blockchain: Proof of Concepts



## Hyperledger Explorer

The screenshot shows the Hyperledger Explorer interface with the following components:

- Navigation tabs: DASHBOARD, NETWORK, BLOCKS, TRANSACTIONS (active), CHAINCODES, CHANNELS.
- Search filters: From: November 21, 2019 12:24 PM, To: November 22, 2019 12:24 PM, Select Orgs, Search, Reset, Clear Filter.
- Transaction table with columns: Creator, Channel Name, Tx Id, Type, Chaincode, Timestamp.
- Terminal window (dark purple background) with the following text:

```
changing custodian of source:  
Store path:/home/si/.hfc-key-store  
Successfully loaded user1 from persistence  
Assigning transaction_id: 859857ba4f18c5dab13c6e40d1269abf319e16abc5dae2f616d62679aa29899e  
Transaction proposal was good  
Successfully sent Proposal and received ProposalResponse: Status - 200, message - ""
```

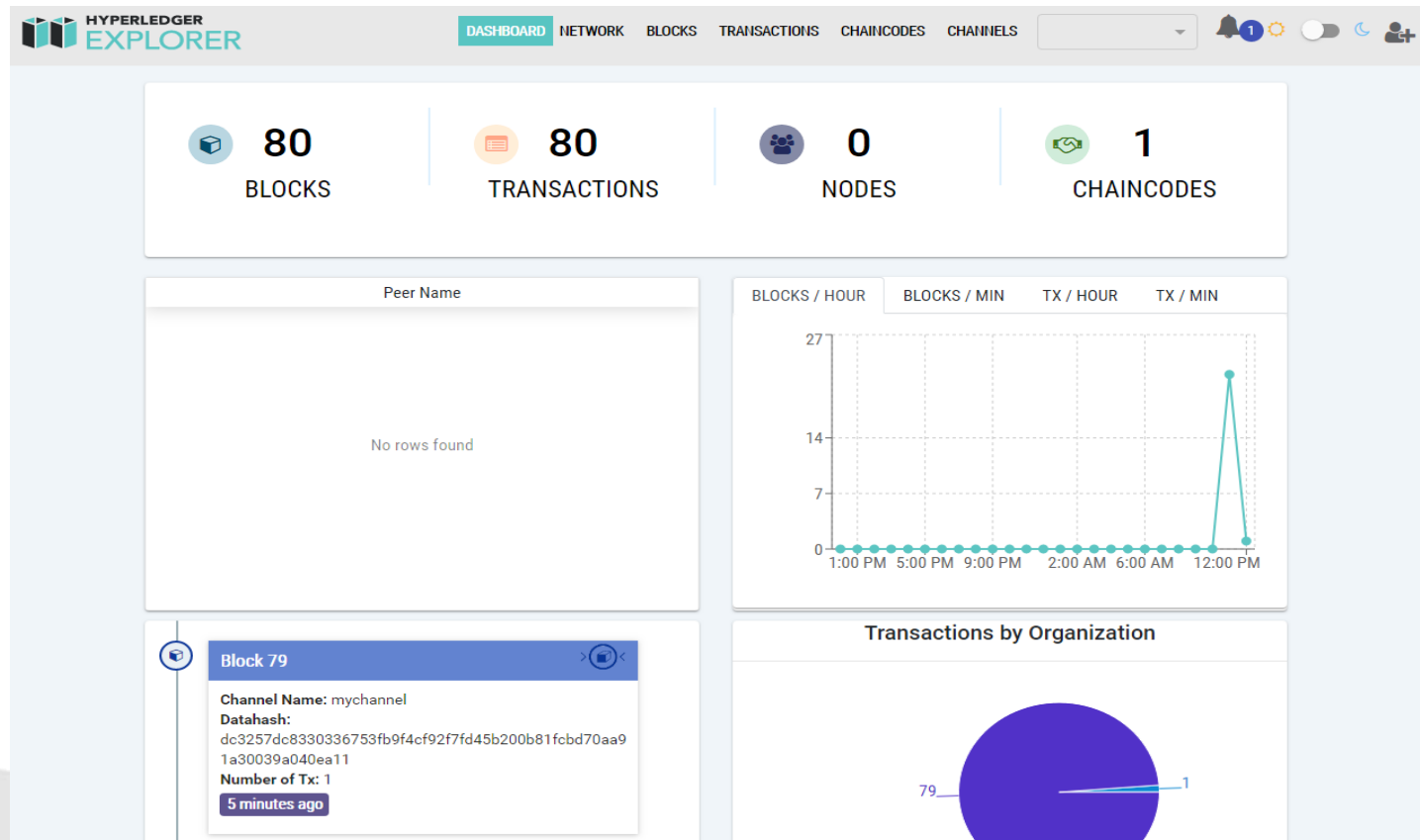
Creator	Channel Name	Tx Id	Type	Chaincode	Timestamp
Org1MSP	mychannel	859857ba4f18c5dab13c6e40d1269abf319e16abc5dae2f616d62679aa29899e	ENDORSER_TRANSA...	nmac-app	2019-11-22T15:18:59...
Org1MSP	mychannel	f09d7f...	ENDORSER_TRANSA...	nmac-app	2019-11-22T14:22:19...
Org1MSP	mychannel	91dff3...	ENDORSER_TRANSA...	nmac-app	2019-11-22T14:20:24...
Org1MSP	mychannel	b9d08f...	ENDORSER_TRANSA...	nmac-app	2019-11-22T14:20:19...



# NMAC Blockchain: Proof of Concepts



## Hyperledger Explorer





# Conclusions and Future Works

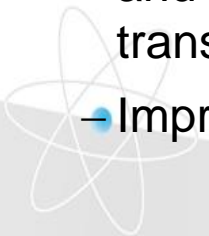


- **Conclusions**

- Nmac-blockchain could improve the current NMAC system.
- This technology bring transparency to nuclear material movements between facilities and different countries.
- Nmac-blockchain reduces costs and delays in the regulator's processes and enhances the security of the information assets helping avoid possible sabotages.

- **Futures works**

- We are going to implements more blockchain peers and evaluate the behaviour and performance of the nmac-blockchain with a large number of concurrent transactions.
- Improve the user experience.



# References



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4. Aspectos básicos de blockchain: Hyperledger Fabric e Hyperleger Composer. Maheshwari S. IBM, developerWorks (2018).
5. Blockchain for dummies, 2nd IBM Limited Edition. Brand W. (2018).
6. Blockchain for Business - An Introduction to Hyperledger Technologies. EdX curses (April, 2019).



# Implementing Blockchain Technology in NMAC system



## Questions?

Thanks for your attention.-



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