无人机低空安全运行策略的思考

Low Altitude Safety Strategy for UAVs

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低空融合空域内运行需要解决的问题

Low Altitude Problems to Resolve

02

感知与避障

Detection &Avoidance

01

时空隔离

Segregated airspace

03

信息融合

Information Convergence

低空运行安全 —— 时空隔离

Low Altitude Safe Operation – Segregated Airspace

地理围栏
Geo-Fence

全球机场禁飞区超18000个

More than 18000 airport restricted zones around the world

- 禁飞区：无法起飞、无法闯入
  Restricted zones: cannot take off or fly in
- 限飞区：飞行高度受限
  Altitude zones: height limited

机场 Airport　　敏感地区 Sensitive area　　国境线 Frontier

地理围栏的发展情况

Development of GEO-Fence

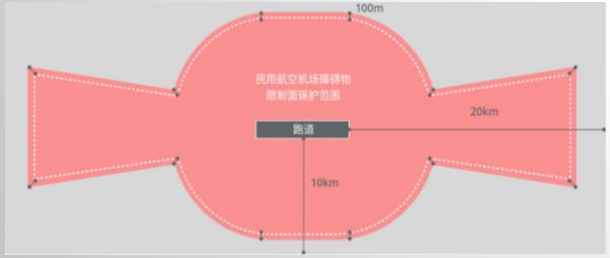
EU 欧洲

GEO-Fence range depends on facility boundaries.
限飞范围基于设施的实际边界

- **Restricted Zones**
- **Authorization Zones**
- **Warning Zones**

China 中国

Airport range based on *Obstacle Limitation Surface.*
机场限飞范围基于*障碍物限制面*



- **Restricted Zones**
- **Altitude Zones**

Review of GEO-Fencing in Europe **欧洲实践的审视**:

- Lack of credible data source

Review of GEO-Fencing in China **中国实践的审视**:

- Airspace is strictly controlled
- Flight is not reasonable in low altitudes

Next Steps 发展路线:

通航机场的应用
Extending GEO-Fence coverage from public airports to general aviation airports.

通过国际民航组织获取更为精确可靠的机场与航路信息
Direct collaboration with ICAO to obtain accurate and credible data for airports and routes.

将直升机航路航线融入地理围栏系统
Integrate helicopter routes into geo-fencing system as a warning tool for UAV operators.

在全球机场引入基于障碍物限制面的立体地理围栏
Introduce 3D GEO-Fencing based on OLS for global airports.

感知与避障

Detection and Avoidance

稳定性与可靠性
Stable and Reliable

毫米波雷达
Millimeter-wave Radar

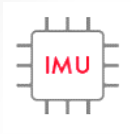
360度多传感器
Multi – sensor Fusion

多系统融合
Air sense & ADS-B

	超声波 Ultrasonic	单目视觉系统 Monocular visual system	红外传感器 Infrared sensor	双目视觉 Stereo visual system	毫米波雷达 Millimeter-wave Radar	广播式自动相关监视系统 ADS-B
可探测范围 Detectable Range	0-10m	0.5-10m	11-12m	20 - 40 m	1.5-100 m	30km+
局限性 Disadvantage	容受干扰 Vulnerable to interference	不能测精确距离 Unable to measure precise distance	距离有限 Limited distance	对光线要求高 High light requirements	体积大，速度慢 Large size and low speed	成本高，兼容问题 High cost and technical compatibility

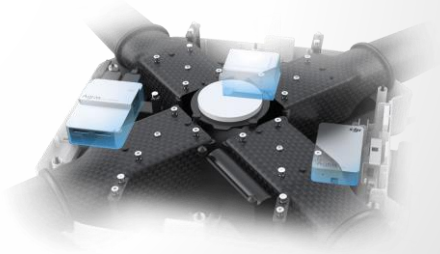
稳定性与可靠性

Flexibility & Reliability



- ✓ 双电池冗余 Dual battery redundancy
- ✓ 双IMU冗余 Dual IMU redundancy
- ✓ 双指南针冗余 Dual compass redundancy
- ✓ 双气压计冗余 Dual barometer redundancy

- ✓ 自主定位 Autonomous positioning
- ✓ IMU计算 IMU calibration
- ✓ 指南针测航向 Directional orientation and navigation
- ✓ 气压计测海拔 Barometer



无人机安全性能

UAV Safety Performance

360°感知系统

360° SENSING SYSTEM

御2 Mavic2	前方（双目视觉） Forward(Binocular visual system)	后方（双目视觉） Backward(Binocular visual system)	上方（红外传感器） Upward（Infrared sensor）	下方（红外传感器） Downward（Infrared sensor）	左右（单目视觉系统） Sides（Monocular visual system）
精确测距范围 Precision Measurement Range	0.5-20 m	0.5至16 m	0.1至8 m	×	×
可探测范围 Detectable Range	20 - 40 m	16至32 m	×	11-12m	0.5-10m
有效避障速度 Effective Sensing Speed	≤ 14m/s	≤ 12m/s	×	×	≤ 8m/s
视角 FOV	水平40°，垂直70° Horizontal: 40°, Vertical: 70°	水平60°，垂直77° Horizontal: 40°, Vertical: 77°	×	×	水平80°，垂直65° Horizontal: 80°, Vertical: 65°

基于ADS-B的航班预警

DJI AirSense and ADS-B

通过接收附近半径数十公里以内的民航客机广播的 ADS-B 信号，分析每台客机的位置、高度、速度等信息，分析双方危险接近和碰撞的风险，并在判断存在碰撞风险的情况下主动避让，大大提升了飞行安全系数。

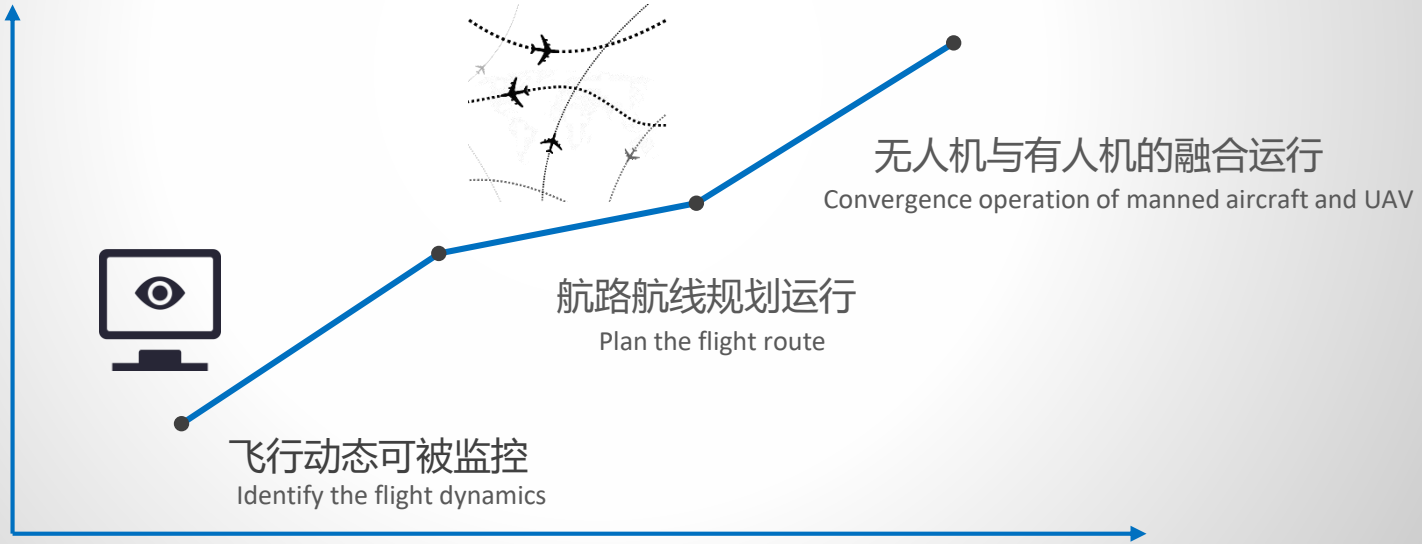
The M200 series features DJI AirSense, a built-in ADS-B receiver, enhancing airspace safety by automatically providing the operator with real-time information about the position, altitude, and velocity of nearby manned aircraft equipped with ADS-B transmitters. AirSense enables safer and more efficient use of airspace, particularly in locations where other aircraft may be operating.

信息融合

Information Convergence

加入UTMISS试点

UTMISS Pilot program



无人机目视试验

Drone VLOS Tests

0.5米
0.5 m

可见光点
Visible Lights

500米
500 m

不可见
Invisible

1000米
1000 m

1.5米
1.5 m

可见轮廓
Visible Outline

500米
500 m

可见光点
Visible Lights

1000米
1000 m

不可见
Invisible

1500米
1500 m

2.1米
2.1 m

可见外形
Visible Shape

500米
500 m

可见轮廓
Visible Outline

1000米
1000 m

较难发现
Hardly visible

1500米
1500 m

低空直升机融合运行试验

Experiment on the convergence operation of helicopter and UAV in low-altitude airspace

海南

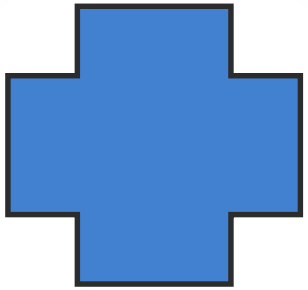
- 飞行信息共享
  Flight Information Exchange
- 规避
  Avoidance
- 告警
  Approach Warning

待解决的问题

Problems to be solved in the work

◆ 完善安全规则

Improve safety rules



◆ 厂商困境

The Dilemma of the manufacturer

操作规则 & 技术规则

Operation rules & Technical rules

技术发展 VS. 法律责任

Technology development VS. Legal liability

谢谢!

THANK YOU